4-9193

FOUNDATION PORE PRESSURE UNDER POTASH WASTE PILES

APPENDIX B

VOLUME I

(PCS MINING, ROCANVILLE DIVISION)

REPORT ON INSTALLATION OF
TAILS PILE INSTRUMENTATION FOR
POTASH CORPORATION OF SASKATCHEWAN
MINING LIMITED – ROCANVILLE DIVISION

CONTRACT NO. M85-3046

VOLUME I – TEXT AND APPENDICES 1 – 3 INC.

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AUG 15 1988
MICROMEDIA

BBT PROJECT NO. S84-1774

DECEMBER 18, 1985

124 pp

BBT Geotechnical Consultants Ltd.

TABLE OF CONTENTS

Page No.

1.0 PROJECT DETAILS

1.1 General Description of the Work — 1
1.2 Development and Scheduling of the Work — 1
1.3 Instrumentation Details — 3
1.4 Site Description — 5

2.0 FIELDWORK

2.1 Site Preparation — 5
2.2 Drilling, Logging and Sampling — 6

2.3 Installation of Instrumentation

2.3.1 Pneumatic Pore Pressure Indicators (Piezometers) — 6
2.3.2 Settlement Sensors — 9
2.3.3 Permanent Benchmark — 9
2.3.4 Installation Difficulties — 10
2.4 Installation of Leads — 11
2.5 Readout Terminal and Pore Pressure Indicator Instrument — 12
2.6 Instrumentation Readings — 12
2.7 Survey Ties — 13

3.0 LABORATORY TESTING

3.1 General — 18
3.2 Subsurface Soil Profile — 19
3.3 Consolidation Testing — 21
3.4 Pore Pressure Response Tests — 22
3.5 Slurry Conductivity Tests — 23
3.6 Carbonate Analyses — 24

4.0 CLOSURE — 25

LIST OF TABLES

Page No.

TABLE I Schedule of Work Activities ———— 2

TABLE II Instrumentation Grid Locations and Elevations ———— 3

TABLE III Instrumentation Components ———— 4

TABLE IV Transducer Serial Nos. and Tubing Lengths ———— 8

TABLE V Summary of Piezometric Observations ———— 14 - 16

TABLE VI Settlement Sensor Observations ———— 17

TABLE VII Summary of Atterberg Limit Tests ———— 19

TABLE VIII Results of Confined Compression Tests on $\bar{B}$ Samples ———— 22

TABLE IX Soil Slurry Conductivity Results ———— 23
TABLE IX a Supplementary Soil Slurry Conductivity Results Following Page 23
TABLE X Soil Carbonate Content Tests ———— 24
TABLE X a Supplementary Soil Carbonate Content Tests Following Page 24

LIST OF APPENDICES

APPENDIX 1 Site Plan
Pilot Hole Logs

APPENDIX 2 Test Hole Logs and Details of Installations

APPENDIX 3 Consolidation Test Results

APPENDIX 4 Pore Pressure Response ($\bar{B}$) Test Results

APPENDIX 5 Grain Size Distribution Curves

APPENDIX 6 Manufacturer's Information

APPENDIX 7 Photographs

APPENDIX 8 Field Notes, Miscellaneous Laboratory Notes and Details

BBT Geotechnical Consultants Ltd.

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January 21, 1986

BBT PROJECT NOS. S84-1746A
S84-1774A

Potash Corporation of Saskatchewan
500, 122 - 1st Avenue South
SASKATOON, Saskatchewan
S7K 7G3

ATTENTION: MR. KEN LAMB, P.ENG.

Dear Sirs:

SUBJECT: SUPPLEMENTARY CARBONATE CONTENT TESTING
PCS INSTRUMENTATION - LC 7046 AND M85-3046
LANIGAN AND ROCANVILLE DIVISIONS

This refers to the addressed subject matter performed by The Saskatchewan Research Council. The results pertaining to each project are listed in the attached Tables I and II.

If there are any questions concerning the above, please do not hesitate to call.

Yours very truly,

BBT GEOTECHNICAL CONSULTANTS LTD.

Barry Meays, P.Eng.

vlm
enc

The table showing supplementary soil carbonate content kit results has been inserted immediately following Page 24 of the volume of the report. The table has been renumbered from Table II to Table Xa

JKDarnell Jan 24/86

BBT Geotechnical Consultants Ltd.
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221 Jessop Avenue
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Feb 5/86

The revisions noted in this letter have been entered into this copy of the report. Page 2 of this letter, which shows a table of soil slurry conductivity test results, has been inserted immediately following Page #23. The table has been renumbered IXa

January 28, 1986
BBT PROJECT NO. S84-1774

Potash Corporation of Saskatchewan
500, 122 - 1st Avenue South
SASKATOON, Saskatchewan
S7K 7G3

ATTENTION: MR. KEN LAMB, P.ENG.

Dear Sirs:

SUBJECT: REVISIONS TO BBT REPORT NO. S84-1774
PCS INSTRUMENTATION - M85-3046
ROCANVILLE DIVISION

This refers to discussions between Mr. Bill Long, P.Eng. and the undersigned on January 10, 1986 regarding the above subject matter.

The identified corrections are listed below:

1. Page 5 - Section 2.1 - 2nd Sentence should read: "The steel casings were installed within 610 mm dry augered drill holes."
2. Page 6 - Section 2.2 - Line 7 should read: "... cohesionless substrata where some samples were obtained using Standard ...".
3. Page 7 - 2nd Paragraph - Line 2 should read: "... filled drill hole to as near as possible to the desired elevation and held in position while the ...".
4. Page 9 - Section 2.3.3 - Last Sentence should read: "Elevation of the permanent benchmark was surveyed to be 481.794 masl geodetic, using the surface of Monument C as an elevation source of 481.648 m on Nov. 7, 1985."
5. Page 11 - Section 2.4 - 2nd Paragraph - Line 6 should read: "... at Nest No. 2A to a common collector trench where the leads were inserted into split electrical duct and then bedded ...".
6. Page 19 - TABLE VII, SUMMARY OF ATTERBERG LIMIT TESTS, 85-68 at Depth 68.6 m - Liquid Limit should be 80.8, not 80.6
   Plasticity Index should be 53.7, not 53.5.

1.0 PROJECT DETAILS

1.1 General Description of the Work

This report provides details relating to various instrumentation installed at the Potash Corporation of Saskatchewan Rocanville minesite during 1985. The instrumentation was concentrated at 2 nest locations beneath the existing tails pile. Instrumentation leads were positioned to a nearby readout station at each nest location. The instrumentation included 9 pneumatic piezometers at a lower tailings pile terrace (Nest No. 1A), 8 pneumatic piezometers and a settlement sensor in a nest (Nest No. 2A) nearer to the top of the tailings pile, and a permanent benchmark north of the tailings pile. Locations of the instrumentation, readout stations and benchmark are shown on Drawing No. S85-1774-1 in Appendix 1.

1.2 Development and Scheduling of the Work

On July 26, 1984, Potash Corporation of Saskatchewan invited tenders for the installation of Tails Pile Instrumentation under accompanying specification RDS-6223 with a closure date of August 16, 1984. A pre-tender meeting was held August 1, 1984, following which Addendum No. 1 was issued on August 14, revising various terms and conditions outlined for the work and extending Tender closure to August 23, 1984. On September 11, 1984, PCS Mining invited a short list of consultants including BBT Geotechnical Consultants Ltd. to re-submit a revised fee proposal to carry out the instrumentation program and to achieve overall cost reductions. The revised proposal was to be in 2 forms; a lump sum/ unit cost basis to comply with a stipulated schedule of items and prices, and a cost estimate for carrying out the program on a fee plus disbursement basis. The revised proposal was submitted on September 19,

1984. Further discussions and negotiations were held with PCS resulting in an ammended proposal dated February 21, 1985. On February 21, 1985, PCS issued a letter of intent to enter into Contract No. M85-3046 with BBT.

Following notification of pending contract award, BBT proceeded immediately with ordering instrumentation components and initial site work. Table I highlights significant dates in the performance of the work.

TABLE I

SCHEDULE OF WORK ACTIVITIES

Notification of Intent to Award Contract and Authorization to Proceed	February 21, 1985
Initial Instrumentation Order	February 27, 1985
Formal Contract Award	March 7, 1985
Installing 400 mm Diameter Corrugated Casings at Nest No. 2A	March 19, 1985
Assembly of Materials and Mobilization to Site	April 28, 1985
Commencement of Drilling and Installation Work	April 30, 1985
Temporary Shutdown of Fieldwork For Re-Evaluation	May 25, 1985
Commence Laboratory Testing	June 17, 1985
Resume Fieldwork and Installations	July 29, 1985
Complete Drilling and Piezometer Installation Work	August 10, 1985
Commence Splicing, Laying Leads and Connections to Readout Terminal	August 11, 1985
Complete Laboratory Testing	November 20, 1985
Complete Final Report	December 18, 1985

1.3 Instrumentation Details

The instrumentation package included 2 principal nests designated as Nest Nos. 1A and 2A. The instrumentation components at each nest are detailed on Table II.

TABLE II

INSTRUMENTATION GRID LOCATIONS AND ELEVATIONS

Piezometer No.	Northing (m)	Easting (m)	Ground Elevation (m)	Tip Elevation (m)
85-50	28,665.00	30,737.30	485.16	476.17
85-51	28,674.10	30,743.95	485.26	470.26
85-52	28,666.21	30,743.09	485.28	467.73
85-53	28,673.53	30,737.85	485.16	452.97
85-54	28,670.04	30,741.28	485.15	462.69
85-55	28,669.55	30,735.48	485.10	464.62
85-56	28,661.90	30,739.40	485.11	446.40
85-57	28,670.35	30,746.70	485.30	444.00
85-58	28,677.45	30,740.75	485.18	440.65
Readout Term.	28,668.75	30,740.91		
85-61	28,257.06	30,407.86	508.01	477.53
85-61 *	28,257.06	30,407.86	508.01	474.48
85-62	28,249.44	30,420.29	507.45	471.48
85-63	28,253.81	30,422.25	507.36	466.82
85-64	28,251.50	30,417.14	507.62	458.64
85-65	28,253.81	30,422.25	507.36	459.20
85-66	28,251.50	30,417.14	507.62	450.01
85-67	28,249.44	30,420.29	507.45	442.22
85-68	28,253.81	30,422.25	507.36	437.71

Settlement Reservoir Elevation (With Cap Removed) = 520.92 m

Readout Term.	28,339.66	30,140.36	
Benchmark	28,772.48	30,124.79	Reference Elevation = 481.794 m

Notes: 1) Piezometer Nos. 85-50 to 85-58 inclusive are at Nest No. 1A

2) Piezometer Nos. 85-61 to 85-68 inclusive are at Nest No. 2A (* - Settlement Gauge).

Components were manufactured by Sinca (Slope Indicator Company Canada Ltd.) and were supplied to part numbers specified in the contract documents. In addition to the installed items, a readout instrument was also provided as part of the work. The principal components were as shown on Table III.

TABLE III

INSTRUMENTATION COMPONENTS

Quantity	**Component**	**SINCA Part No.**
1	Settlement Transducer	51416300
1	Settlement Reservoir	51419500
	Five Tube/~~Electrica~~l Cable (Settlement)	50705101
4	Pneumatic Terminal Pipe	51409900
17	Pore Pressure Transducer	51417800
	Nylon Triple Piezometer Tubing	51404700
1	Portable Pneumatic Indicator	51401101
1	AFC Option for Above Indicator	51401120
4	6-Position Terminal Pipe	51409900

Details of the supplied equipment and related technical information is included under Appendix 6.

1.4 Site Description

The site of the installation work was on the existing tailings pile. Nest No. 1A instrumentation was installed on a lower tailings pile terrace which existed at the time, bordering the access road to the top of the pile immediately south of the existing brine pond. The height of the existing tailings pile at Nest No. 1A at the time of drilling varied between 11.0 to 12.0 m. The instrumentation at Nest No. 2A was nearer to the top of the tailings pile near the southeast corner. The height of the existing tailings pile at the location of Nest No. 2A at the time of drilling varied from 30.5 to 32.2 m. The locations of the nest sites are shown on Drawing No. S84-1774-1. Access to the nest sites with the drill rig and accessories were afforded along an existing access route cut through the tailings by mine equipment and/or by traversing former tailings terraces.

2.0 FIELDWORK

2.1 Site Preparation

Initial site preparation consisted of having 400 mm diameter corrugated steel casing 12.2 m long installed at 10 locations at the proposed location of Nest No. 2A. The steel casings were installed within 610 mm dry augered drill holes~~, and the annulus was backfilled with 20 MPa sulphate resisting concrete.~~

Revision
Jan 28/86

Subsequent site preparation consisted of creating a mound of salt upstream of Nest No. 2A to act as a barrier against brine flowing down from the top of the tailings pile. This service was provided by PCS.

Instrumentation was installed at Nest No. 1A directly from the existing tailings surface without any site preparation.

2.2 Drilling, Logging and Sampling

Drilling of the test holes was performed with BBT's Model 1250 Failing rotary drill using wet drilling methods. Because of the difficult drilling conditions in this area, casing, either 127 mm or 165 mm O.D., was used as part of the drilling technique to advance each test hole. Soil samples were obtained for laboratory testing generally by using HQ size (63.5 mm core) diamond coring equipment, except within cohesionless substrata where some samples were obtained using Standard Penetration equipment or wash cutting returns. Electric logging of the pilot hole was performed at both Nest Nos. 1A and 2A. Difficulties were encountered in obtaining repeatable E-Logs and this was attributed to the very high conductivities recorded in the drilling fluid due to ingress of brine.

← Revision Jan 28/86

The test holes and piezometer installations were completed at Nest No. 1A before commencing work on Nest No. 2A. Initially, great difficulty was encountered at Nest No. 2A in endeavoring to penetrate the extreme concentration of cobbles and boulders at the base of the tailings. These difficulties will be outlined in Subsection 2.3.4 of this report.

2.3 Installation of Instrumentation

2.3.1 Pneumatic Pore Pressure Indicators (Piezometers)

Piezometer tip assemblies were supplied as a unit comprised of the pore pressure transducer integral with a predetermined length of nylon triple tubing. The tubing was adequate to extend well above ground level from the anticipated tip elevation. Most of the piezometers were installed in the drill holes as a pre-fabricated assembly consisting of the piezometer tip encased in a canvas bag filled with graded frac sand, a series of mesh enclosures filled with bentonite pellets (above the canvas bag) and a ballast weight fastened to the bottom of the canvas bag. Piezometer Nos. 85-50 and 85-61 were installed as above except that the mesh enclosure filled with bentonite pellets was not included. Photograph Nos. 1 and 6 in Appendix 7 show typical pore pressure transducer and tip, sand encasement, ballast weight and seal assemblies.

The complete prefabricated piezometer assembly was lowered in the fluid-filled drill hole ~~to~~ as near as possible to the desired elevation and held in position while the bentonite pellet seal was allowed to swell. The drill hole column above the bentonite seal was filled with Type 50 cement-bentonite-water slurry grout which was placed from the bottom up, displacing the drilling fluid. ← Revision Jan 28/86

At Nest No. 1A, each piezometer was installed in a separate drill hole. At Nest No. 2A, 2 installations were combined in 1 test hole, and 3 piezometers were installed in 1 other test hole. This procedure was necessitated due to the difficult drilling conditions encountered at Nest No. 2A. Details of individual and combined piezometer installations are shown on the Test Hole Log and Piezometer Detail Plots, Drawing Nos. S84-1774-4 to S84-1774-18 contained in Appendix 2. Table IV outlines transducer Serial Numbers and tubing lengths for all of the piezometer installations.

TABLE IV

TRANSDUCER SERIAL NOS. AND TUBING LENGTHS

Installation No.	Transducer Serial No.	Total Tubing Length To Readout Terminal (m)
85-50	23711	19
85-51	23706	25
85-52	23700	25
85-53	23707	43
85-54	23708	30
85-55	23701	31
85-56	23702	50
85-57	23715	53
85-58	23712	56
85-61	23710	324
85-62	23714	341
85-63	23703	345
85-64	23709	354
85-65	23698	353
85-66	23499	363
85-67	23704	370
85-68	23705	375
85-61 (Settlement Transducer)	24412	327

2.3.2 Settlement Sensors

The settlement sensor assembly was supplied as a complete unit which included the transducer and sufficient lead to extend to the terminal house location. This pre-assembly was used in order to avoid the very difficult procedure of splicing the liquid filled lead for this installation. Photograph Nos. 5 and 11 in Appendix 7 show typical transducer and associated surface installation. Calibration data for the sensor is included with the Manufacturer's information in Appendix 6. Table IV outlines transducer serial Nos. and tubing lengths.

2.3.3 Permanent Benchmark

The permanent benchmark was fabricated and installed in accordance with the requirements of the Technical Specification. A copy of Drawing 30317B from the noted specification is included under Appendix 2. The deep benchmark was installed in a rotary drill hole, with the assembly being driven below the base of the drill hole to achieve seating of the drive shoe. Water pump grease was placed above the drive shoe within the outer pipe, and the annulus between pipes was filled with heavy oil after installation. Elevation of the permanent benchmark was surveyed to be 481.794 masl geodetic, using the surface of Monument C as an elevation source of 481.648 m on Nov. 7, 1985

← Revision
Jan 28/86

2.3.4 Installation Difficulties

Some significant difficulties were encountered in the installation work and are listed below together with mitigative actions taken, where applicable.

i) After Nest No. 1A was completed, initial drilling conditions at Nest No. 2A proved to be very difficult due to the presence of approximately 2.0 m to 3.0 m of predominantly cobbles and boulders encountered at the base of the tailings pile in this vicinity. On the dates of May 9 and May 22, 23 and 24, 1985, 2 test holes were initially attempted and at neither one could the casing be advanced and seated below the granular layer. One of these holes was then partially grouted through the casing, and the other one was abandoned, with the casing left in the test hole.

   When field work resumed on July 29, 1985, the 2 test holes previously abandoned were reattempted, and used as Test Hole Nos. 85-61 and 85-68. Renewed efforts eventually overcame the problems previously identified.

ii) During field drilling of Test Hole No. 85-66, tailings return was absent. Approximately 600 gallons of mixed drill mud accompanied with 2 bags of bran, 1 pail of bentonite pellets and some grout was pumped into the test hole in an effort to seal it off.

iii) During field drilling, the core sample recovery was not as good as desired due to the presence of numerous cobbles and/or boulders present within the glacial till strata.

2.4 Installation of Leads

The piezometer leads at Nest No. 1A were not spliced as sufficient lead was available to the readout terminal which was located in the approximate centre of the individual test holes. A layer of tailings approximately 1.0 m thick was used to cover the leads and act as a platform through which the terminal leads and pipe protruded and upon which the terminal building was placed.

All piezometer leads at nest No. 2A were spliced in the vicinity of the well head and extended in trenches from the well head to the readout terminal. Mechanical splices were used and were completely encased in a molded epoxy sleeve after splicing, all as recommended by the manufacturer. Individual trenches were made from the well head location at Nest No. 2A to a common collector trench where the leads were inserted into split electrical duct and then bedded in tailings and extended to the readout terminal.

Revision — Jan 28/86

In general, piezometers were read prior to splicing leads, after splicing leads and after connection to the terminal facility. The readings did not indicate any anomalous conditions at any of the stages and all splices and connections were indicated to be sound. Drawing No. S84-1774-1 in Appendix 1 shows location of the piezometer lead runs. Photograph Nos. 2, 3, 7, 8 and 9 in Appendix 7 show details of splicing, trenching and routing of leads. Table IV provides lengths of tubing to each piezometer and settlement sensor.

The lead for the settlement sensor was laid in a similar manner to the piezometer leads, except that no splicing was involved.

2.5 Readout Terminal and Pore Pressure Indicator Instrument

Manufacturer's readout terminal facilities were supplied for all instrument lead terminations. Individual instrumentation terminals were identified with embossed labels. A small building to house each of the 2 terminals was provided by PCS. Appendix 6 contains Manufacturer's information relating to the terminal facilities. Photograph Nos. 4, 10 and 11 in Appendix 7 show details of the terminal pipes and connections.

The pore pressure indicator instrument supplied for the work was as specified in the contract, being Slope Indicator Co. Portable Pneumatic Indicator No. 51401101 c/w Automatic Flow Control (AFC) option No. 51401120 for use in reading settlement sensors. Manufacturer's information regarding this equipment is contained in Appendix 6.

2.6 Instrumentation Readings

Observations were taken on piezometers at several stages during the installation process. Observations during splicing and connection operations were noted under Section 2.4. In addition, observations were made shortly after installation in the drill hole, after the seal had been allowed to expand and after grouting. Prior to installation, all tips were allowed to saturate as per Manufacturer's recommendations, and response tested before assembly for installation.

Table V summarizes various observations of the piezometers.

The settlement sensor was observed after connection to the reservoirs at the readout terminal. Table VI shows settlement sensor observations for two dates.

2.7 Survey Ties

Horizontal survey ties were established to instrumentation points by means of an EDM survey traverse originating from minesite survey control points. Accuracy of survey closure was 1:13,000. All locations were reduced to the minesite coordinate system provided by PCS and are shown (converted to metric equivalents) on Table II.

Vertical survey control was established to all instrumentation locations from a minesite monument "C" located approximately 9.0 m north of the permanent benchmark installed under this work, and having a geodetic elevation of 481.648 m. Elevations of below ground installations were established by vertical measurements from the drill hole collar. Relevant elevation data are shown on Table II.

TABLE V

SUMMARY OF PIEZOMETRIC OBSERVATIONS

Installation No.	Tip Elevation (m)	Reading Before Grouting				Reading After Grouting			
		Date	PSI	m of Water	Water Level Elev. (m)	Date	PSI	m of Water	Water Level Elev. (m)
85-50*	476.17	May 8	7.5	5.27	481.44				
85-51	470.26	May 8	21.4	15.05	485.31				
85-52	467.73	May 8	23.5	16.52	484.25				
85-53	452.97	May 6	45.2	31.78	484.75				
85-54	462.69	May 8	26.2	18.42	481.11				
85-55	464.62	May 7	25.4	17.86	482.48				
85-56	446.40	May 3	52.6	36.98	483.38	May 3	60.2	42.3	488.73
85-57	440.00	May 1	56.5	39.73	483.73	May 3	55.2	38.81	482.81
85-58	440.65	May 4	60.6	42.61	483.26				
85-61*	477.53								
85-62	471.48								
85-63	466.82	Aug. 8	18.0	12.66	479.48				
85-64	458.64								
85-65	459.20	Aug. 1	57.1	40.15	499.35	Aug. 8	37.9	26.65	485.85
85-66	450.01								
85-67	442.22	Aug. 1	67.5	47.45	489.68	Aug. 8	85.3	59.97	502.19
85-68	437.71	July 30	103.6	72.82	510.53	Aug. 8	92.0	64.69	502.40

* No Grout in These Installations.

continued . . .

TABLE V (continued)

Installation No.	Tip Elevation (m)	Reading After Grouting							
		Date	PSI	m of Water	Water Level Elev. (m)	Date	PSI	m of Water	Water Level Elev. (m)
85-50*	476.17								
85-51	470.26								
85-52	467.73								
85-53	452.97	May 7	45.2	31.78	484.75				
85-54	462.69								
85-55	464.62								
85-56	446.40	May 6	51.0	35.86	482.26				
85-57	444.00	May 6	55.4	38.95	482.95				
85-58	440.65	May 6	60.6	42.61	483.26				
85-61*	477.53	Aug. 10	4.5	3.16	480.69	Aug. 11	4.5	3.16	480.69
85-62	471.48	Aug. 10	9.5	6.79	478.27	Aug. 11	9.6	6.75	478.23
85-63	466.82	Aug. 10	16.5	11.60	478.42	Aug. 11	16.4	11.53	478.53
85-64	458.64	Aug. 10	26.5	18.63	477.27	Aug. 11	26.5	18.63	477.27
85-65	459.20	Aug. 10	37.5	26.37	485.57	Aug. 11	37.6	26.44	485.64
85-66	450.01	Aug. 10	41.3	29.04	479.05	Aug. 11	41.5	29.18	479.19
85-67	442.22	Aug. 10	86.0	60.47	502.69	Aug. 11	86.4	60.75	502.97
85-68	437.71	Aug. 10	92.8	65.25	502.96	Aug. 11	92.5	65.04	502.75

* No Grout in These Installations.

continued . . .

TABLE V (continued)

Installation No.	Tip Elevation (m)	Date	PSI	m of Water	Water Level Elev. (m)	Date	PSI	m of Water	Water Level Elev. (m)
85-50*	476.17	May 9	7.5	5.27	481.44	May 23	7.5	5.27	481.44
85-51	470.26	May 9	18.0	12.66	482.92	May 23	16.5	11.60	481.86
85-52	467.73	May 9	19.2	13.50	481.23	May 23	19.0	13.36	481.09
85-53	452.97	May 9	42.5	29.88	482.85	May 23	40.2	28.26	481.23
85-54	462.69	May 9	26.5	18.63	481.32	May 23	26.0	18.28	480.97
85-55	464.62	May 9	23.5	16.52	481.14	May 23	23.0	16.17	480.79
85-56	446.40	May 9	51.3	36.07	482.47	May 23	51.0	35.86	482.26
85-57	444.00	May 9	56.0	39.37	483.37	May 23	55.0	38.67	482.67
85-58	440.65	May 9	60.0	42.19	482.84	May 23	59.4	41.76	482.41
85-61*	477.53	Aug. 14	4.6	3.23	480.76	Aug. 15	4.6	3.23	480.76
85-62	471.48	Aug. 14	8.8	6.19	477.67	Aug. 15	8.8	6.19	477.67
85-63	466.82	Aug. 14	16.1	11.32	478.14	Aug. 15	16.0	11.25	478.07
85-64	458.64	Aug. 14	26.5	18.63	477.27	Aug. 15	26.5	18.63	477.27
85-65	459.20	Aug. 14	36.0	25.31	484.51	Aug. 15	35.5	24.96	484.16
85-66	450.01	Aug. 14	42.2	29.67	479.68	Aug. 15	42.1	29.60	479.61
85-67	442.22	Aug. 14	87.1	61.24	503.46	Aug. 15	87.4	61.45	503.67
85-68	437.71	Aug. 14	93.5	65.74	503.45	Aug. 15	93.2	65.53	503.24

* No Grout in These Installations.

TABLE VI

SETTLEMENT SENSOR OBSERVATIONS

Settlement Gauge No.	Initial Tip Elevation (m)	Top of Settlement Reservoir (With Cap Removed) (m)	Date	Gauge Readings (psi)	m of Head	Settlement Plate Elev. (m)
85-61	474.48	520.92	Aug. 15	69.7	45.12	475.80
85-61	474.48	520.92	Aug. 16	69.7	45.12	475.80

3.0 LABORATORY TESTING

3.1 General

A comprehensive laboratory testing program was provided and was generally as outlined in the Technical Specification with a few minor modifications. The most important modification was outlined in PCS letter addressed to BBT dated September 25, 1985, which outlined a significant reduction in the number of $\bar{B}$ tests originally requested. All laboratory testing was performed in-house by BBT, with the exception of carbonate analyses which were performed by Saskatchewan Research Council.

Some deviations from the general testing format were necessary due to the nature of some of the samples. Laboratory classifications were performed on all samples tested and this information was incorporated in the subsurface test hole logs shown on Drawing Nos. S84-1774-4 to S84-1774-18. Results of index testing such as moisture content, Atterberg limits and density are also shown on the aforenoted test hole logs in Appendix 2.

For ease of reference, Atterberg limit test results have been summarized in Table VII together with the corresponding natural moisture contents for the tested samples.

Grain size distribution tests were conducted on representative samples and the curves are contained in Appendix 5, Drawing Nos. S84-1774-19 to S84-1774-34 inclusive.

3.2 Subsurface Soil Profile

The subsurface soil conditions at each instrumentation elevation have been shown on the test hole logs, as discussed under Section 3.1. In addition, a comprehensive subsurface soil profile was prepared, based on results of field logging, laboratory classification and testing, and E-Logging of the pilot holes. The comprehensive profile is shown on Drawing Nos. S84-1774-2 and S84-1774-3 in Appendix 1. Photograph No. 12 in Appendix 7 shows a portion of a core sample obtained from Test Hole No. 85-68 at nest No. 2A at the depth indicated.

TABLE VII

SUMMARY OF ATTERBERG LIMIT TESTS

Test Hole No.	Depth Below Ground Surface (m)	Measured Water Content (%)	Plastic Limit	Liquid Limit	Plasticity Index
85-53	13.7 - 15.2	10.7	15.0	33.0	18.0
85-53	16.0	——	14.0	24.0	10.0
85-53	20.3 - 20.4	——	14.0	23.0	9.0
85-53	21.9 - 22.1	——	14.0	26.0	12.0
85-53	23.0 - 23.2	9.1	15.0	26.0	11.0
85-53	23.9 - 24.1	9.6	15.0	28.0	13.0
85-53	30.8	16.0	17.0	39.0	22.0
85-53	31.7	——	18.0	35.0	17.0
85-58	38.1 - 38.3	9.2	17.0	36.0	19.0
85-58	39.7 - 39.9	13.5	16.0	37.0	21.0
85-58	40.7 - 40.8	22.5	24.0	79.0	55.0
85-58	42.8 - 43.0	19.0	25.0	96.0	71.0
85-58	43.6	19.7	26.0	91.0	65.0
85-68	35.4	10.9	17.9	29.8	11.9
85-68	38.0 - 38.1	18.9	17.0	19.7	2.7
85-68	43.5 - 43.6	9.1	15.4	20.5	5.1
85-68	45.2 - 45.3	10.6	15.0	27.0	12.0
85-68	50.7	11.8	15.5	26.2	10.7
85-68	57.9	19.3	17.8	38.5	20.7
85-68	60.4	14.4	16.0	37.0	21.0
85-68	64.2 - 64.3	28.0	30.3	108.0	77.7
85-68	65.8	23.4	28.8	88.2	59.4
85-68	67.1	20.6	27.9	102.0	74.1
85-68	68.6	19.7	27.1	~~80.6~~ 80.8	~~53.5~~ 53.7

Δ Revision Jan 23/86

The general subsurface profile developed at Nest No. 1A was as follows:

Potash Tailings	to 11.5 m
Clay Till - moist, stiff to hard, brown	to 13.6 m
Clay Till - moist, stiff to hard, grey	to 18.3 m
Sand - poorly graded, fine to medium grained, grey	to 18.6 m
Clay Till - moist, low to medium plastic, stiff to hard, grey	to 19.6 m
Sand - silty, poorly graded, fine-grained, grey	to 21.0 m
Clay Till - moist, very stiff to hard, low to medium plastic, grey	to 40.0 m
Clay Shale - damp, hard, high plastic, grey silty	to 45.4 m

The general subsurface soil profile developed at Nest No. 2A was as follows:

Potash Tailings	to 31.4 m
Gravel - sandy, cobbles and boulders	to 35.3
Clay Till - moist, hard, low to medium plastic, grey	to 36.5 m
Sand - fine grained, grey	to 36.8 m
Clay Till - moist, hard, low to medium plastic, grey	to 38.3 m
Sand - fine grained, grey	to 38.6 m
Clay Till - moist, hard, low to medium plastic, grey.	to 38.9 m

Sand - fine to medium grained, poorly graded, grey, uniform, trace silt	to 40.7 m
Clay Till - silty, moist, very stiff to hard, low to medium plastic, grey	to 41.3 m
Sand - fine, grey	to 41.6 m
Clay Till - silty, moist, very stiff to hard, low to medium plastic, grey	to 42.7 m
Sand - fine, grey	to 42.9 m
Clay Till - silty, moist, very stiff to hard, low to medium plastic, grey, few cobbles	to 63.7 m
Clay Shale - damp, hard, high plastic, grey	to 70.1 m

It is to be noted that the developed profile represents information from sources separated by a few metres and that the exact profile at a particular point could vary.

3.3 Consolidation Testing

Consolidation tests, without rebound, were conducted on soil samples from most piezometer tip locations, except where samples suitable for testing were unavailable. Slight difficulties were experienced during consolidation testing (due to the vertical dial gauge sticking) at a certain point on 2 separate samples (Test Hole No. 85-53 at 31.1 to 31.2 m and Test Hole No. 85-68 at 43.0 m), which resulted in one erratic dial reading versus log time curve being plotted on each of the aforementioned tests. Results of consolidation testing are shown in Appendix 3 and include plots of dial reading vs log time, dial reading vs square root time, strain vs pressure, void ratio vs log pressure and modulus vs pressure.

3.4 Pore Pressure Response Tests

Pore pressure response ($\bar{B}$) tests were conducted in triaxial test cells. Tests were conducted on selected samples as outlined in PCS letter addressed to BBT dated September 25, 1985. Plots of $\bar{B}$ response test results are shown in Appendix 4. The $\bar{B}$ test procedure is outlined in Appendix B.

Following completion of the $\bar{B}$ response test, the soil samples were failed in axial compression at a relatively high rate of strain. Results of this testing to failure are shown on Table VIII. Related laboratory test data are shown in Appendix 8.

TABLE VIII

RESULTS OF CONFINED COMPRESSION TESTS ON $\bar{B}$ SAMPLES

Test Hole No.	Sample Depth (m)	Confining Pressure (kPa)	Failure Stress (kPa)	Percent Strain
85-53	15.9 - 16.7	689.5	553.7	18.1
85-58	38.5 - 38.6	689.5	401.9	20.0
85-58	41.1 - 41.2	776.3	409.2	20.0
85-68	37.6 - 37.7	758.4	101.9	16.5
85-68	42.8 - 43.0	758.4	1446	20.0
85-68	66.9 - 67.3	758.4	1729	3.0

3.5 Slurry Conductivity Tests

Slurry conductivity tests were conducted on selected samples as requested by PCS. Results of slurry conductivity testing are shown on Table IX. The slurry conductivity lab test procedure is included in Appendix 8.

TABLE IX

SOIL SLURRY CONDUCTIVITY RESULTS

Test Hole No.	Depth (m)	Conductivity (umhos/cm)
85-53	13.7 - 15.2	8,550
85-53	20.3 - 20.4	16,290
85-53	21.2 - 21.3	13,370
85-53	22.4 - 22.6	6,790
85-53	23.3 - 23.5	10,780
85-53	30.8 - 31.1	10,000
85-53	31.7	11,990
85-58	38.1 - 38.3	11,770
85-58	40.7	8,540
85-58	43.6	12,590
85-68	35.4	159,900
85-68	36.6	171,800
85-68	37.2	107,100
85-68	38.0	89,660
85-68	38.2	114,900
85-68	40.7	48,060
85-68	41.5	41,360
85-68	42.0	38,880
85-68	43.3	12,020
85-68	45.2	5,050
85-68	45.6	4,320
85-68	43.5	8,430

See following page
for additional soil
slurry conductivity
test Results.

Revision
Jan 28/86

With reference to your inquiry regarding the large difference in soil slurry conductivity results between the upper portions of Nests 1A and 2A, additional tests were conducted at various depths in the 2 nests. The results are tabulated below:

~~TABLE I~~ TABLE IXa

SUPPLEMENTARY SOIL SLURRY CONDUCTIVITY RESULTS

Test Hole No.	Depth (m)	Conductivity (umhos/cm)
85-53	20.3	12,910
85-53	21.2	7,070
85-53	30.8	7,070
85-58	38.1	12,190
85-68	35.4	139,550
85-68	38.2	104,100
85-68	40.7	53,050
85-68	43.3	14,820

Six copies of this letter are included. One copy should be appended to each copy of the report previously issued.

Yours very truly,

BBT GEOTECHNICAL CONSULTANTS LTD.

Barry Meays

B. Meays, P.Eng.

ks

enc

3.6 Carbonate Analyses

Carbonate analyses were conducted on selected till samples as requested by PCS. These analyses were performed by the Saskatchewan Research Council and results are shown on Table X.

TABLE X

SOIL CARBONATE CONTENT

Test Hole No.	Depth below Ground Surface (m)	CO_3 Content (% Solids - Dry Soil Weight)
85-53	16.0 - 16.8	12
85-53	20.7 - 20.9	11
85-53	30.6	12
85-58	39.0 - 39.4	13
85-68	37.7 - 37.8	12.7
85-68	43.3 - 43.4	12.1
85-68	45.7 - 45.8	15.5

See following page for supplementary soil carbonate content test results

TABLE Xa

~~TABLE II~~

PCS ROCANVILLE INSTRUMENTATION

SOIL CARBONATE CONTENT

Test Hole No.	Depth Below Ground Surface (m)	CO_3 Content (% Solids - Dry Soil Weight)
85-53	16.2	8.8
85-53	20.3 - 20.4	8.9
85-53	31.1	15.0
85-68	35.4 - 35.7	9.6
85-68	37.2	8.5
85-68	50.3	10.0
85-68	50.7	8.9

This table shows the supplementary soil carbonate content tests referred to in BBT's letter dated Jan 21/86 A copy of the letter may be found toward the front of this volume

Jan 24/86

4.0 CLOSURE

The findings and information presented in this report were prepared in accordance with generally accepted professional engineering principles and practice. The information was based upon results of field and laboratory investigations, combined with data provided by manufacturers. If conditions are encountered during operation or review that appear to be different from those shown by this report, this office should be notified.

Respectfully submitted,

BBT GEOTECHNICAL CONSULTANTS LTD.

Barry Meays

B.D. Meays, P.Eng.

B. D. MEAYS

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS
OF SASKATCHEWAN
CERTIFICATE OF
AUTHORIZATION NO. 185
BBT GEOTECHNICAL
CONSULTANTS LTD.

Dennis Matthews, P.Eng.

BDM:DM:vlm

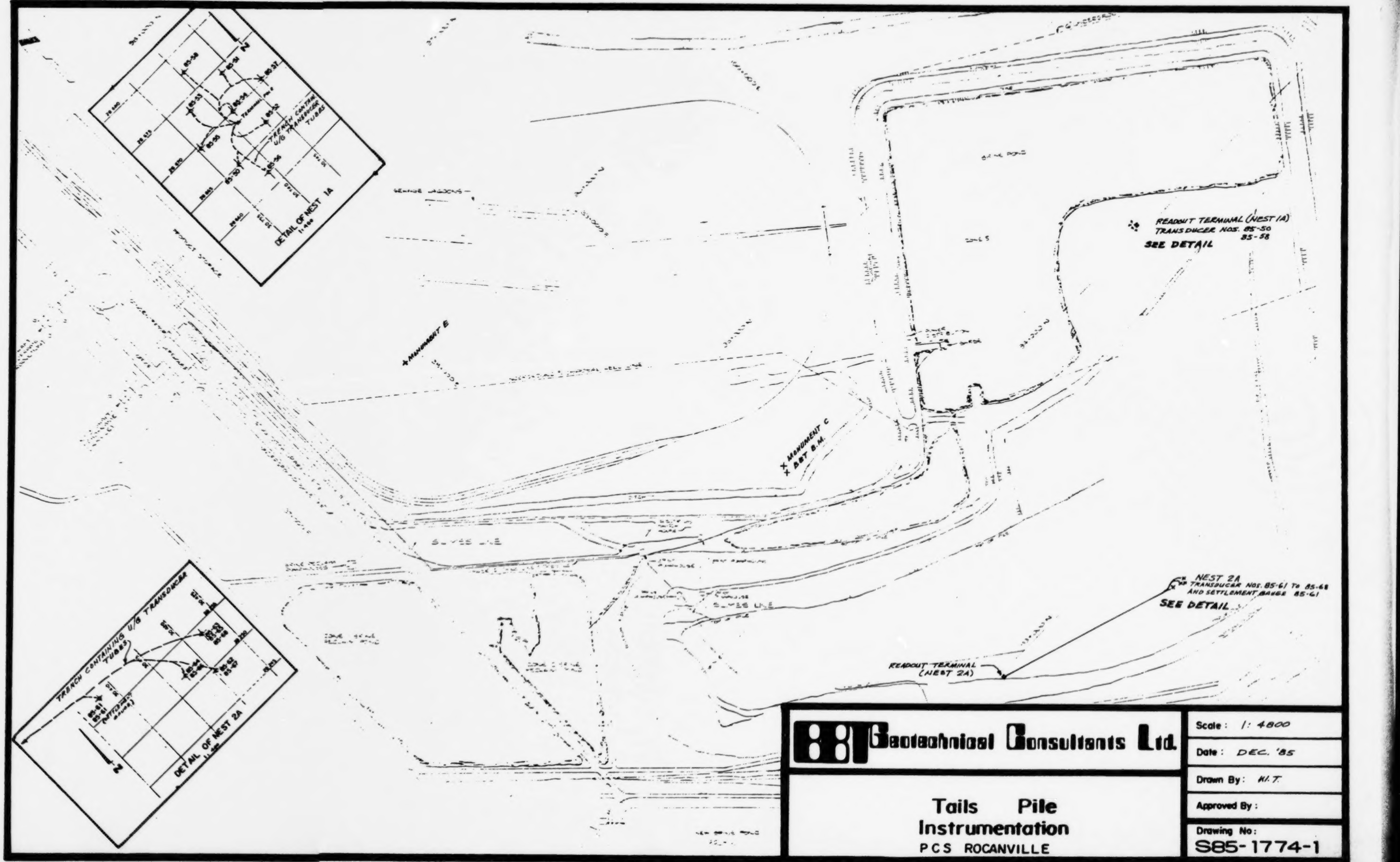
APPENDIX 1

Site Plan and Pilot Hole Logs

APPENDIX 1

Site Plan and Pilot Hole Logs

Site Plan	S84-1774-1
Pilot Hole Log and E-Log at Nest No. 1A	S84-1776-2
Pilot Hole Log and E-Log at Nest No. 2A	S85-1774-3


DETAIL OF NEST 1A
1:400
N
85-58
85-51
85-57
85-53
85-54
85-52
85-55
85-56
85-50
TRENCH CONTAIN U/G TRANSDUCER TUBES
READOUT TERMINAL (NEST 1A)
TRANSDUCER NOS. 85-50
85-58
SEE DETAIL
MONUMENT E
X MONUMENT C
X BBT B.M.
SYKES LINE
NEST 2A
TRANSDUCER NOS. 85-61 To 85-68
AND SETTLEMENT GAUGE 85-61
SEE DETAIL
READOUT TERMINAL
(NEST 2A)
TRENCH CONTAINING U/G TRANSDUCER TUBES
DETAIL OF NEST 2A
N

BBT Geotechnical Consultants Ltd.

Scale: 1: 4800

Date: DEC. '85

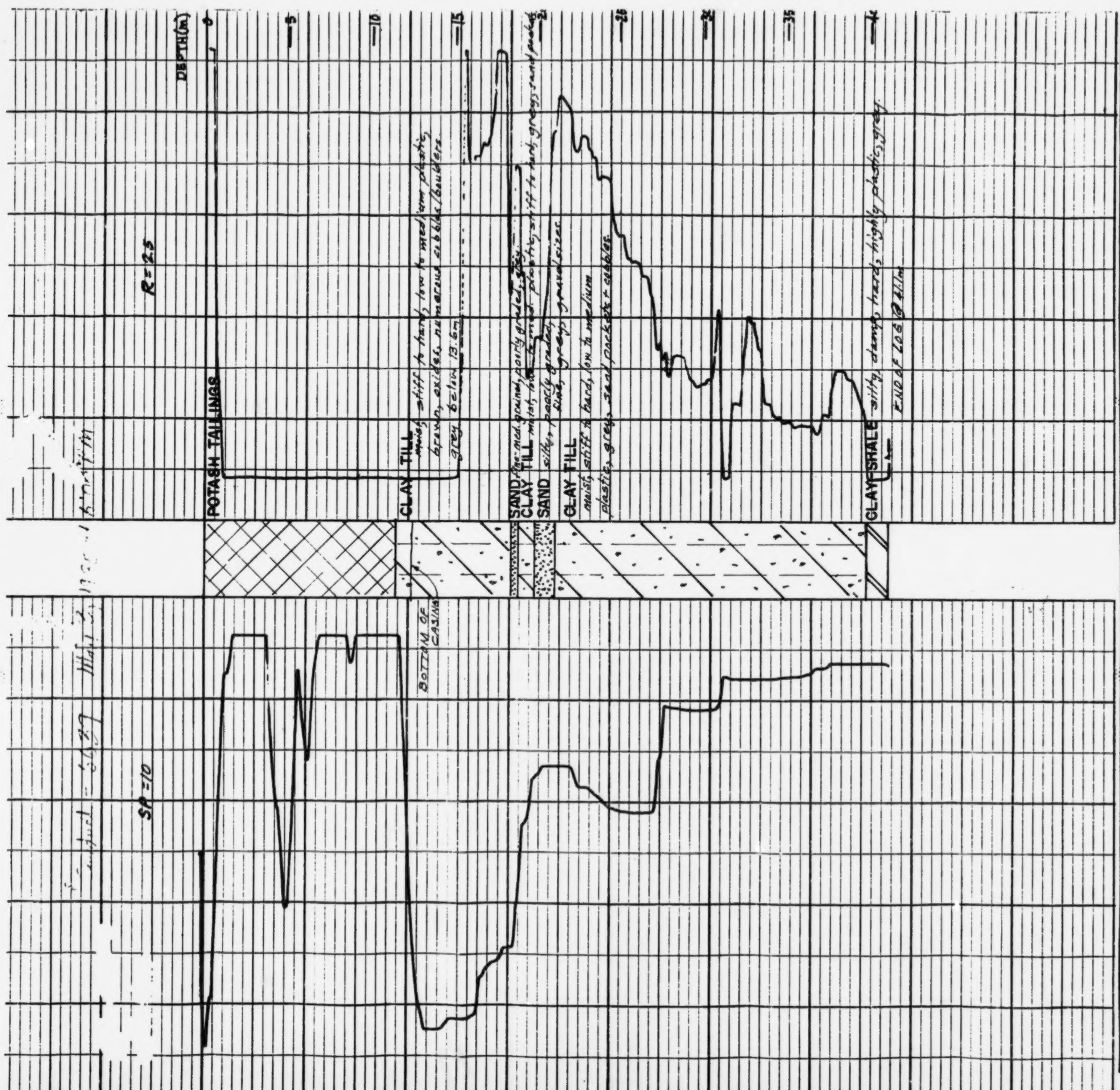
Drawn By: K.T.

Approved By:

Tails Pile Instrumentation

PCS ROCANVILLE

Drawing No:
S85-1774-1



TEST HOLE 85-58

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITION MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME

DRILLER: OSCAR SCHMIDT

LOGGER OPERATOR: OSCAR SCHMIDT

DEPTH DRILLED 45.4 m

DEPTH LOGGED 41.1 m

CONDUCTIVITY (µmhos/cm at 25°C)

DRILLING WATER -

DRILLING FLUID 6639

DATE STARTED

DATE COMPLETED MAY 3, 1985

DATE LOGGED MAY 3, 1985

NAME & MODEL OF LOGGER

LOGGER S/N

BIT S/N

SPONTANEOUS POTENTIAL 10 millivolts/inch

SINGLE-POINT RESISTANCE 2.5 millivolts/inch

GRAVEL	SAND	SILT	CLAY	ORGANIC
⁘	░	▥	▨	⸾

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.

ELECTRIC LOG

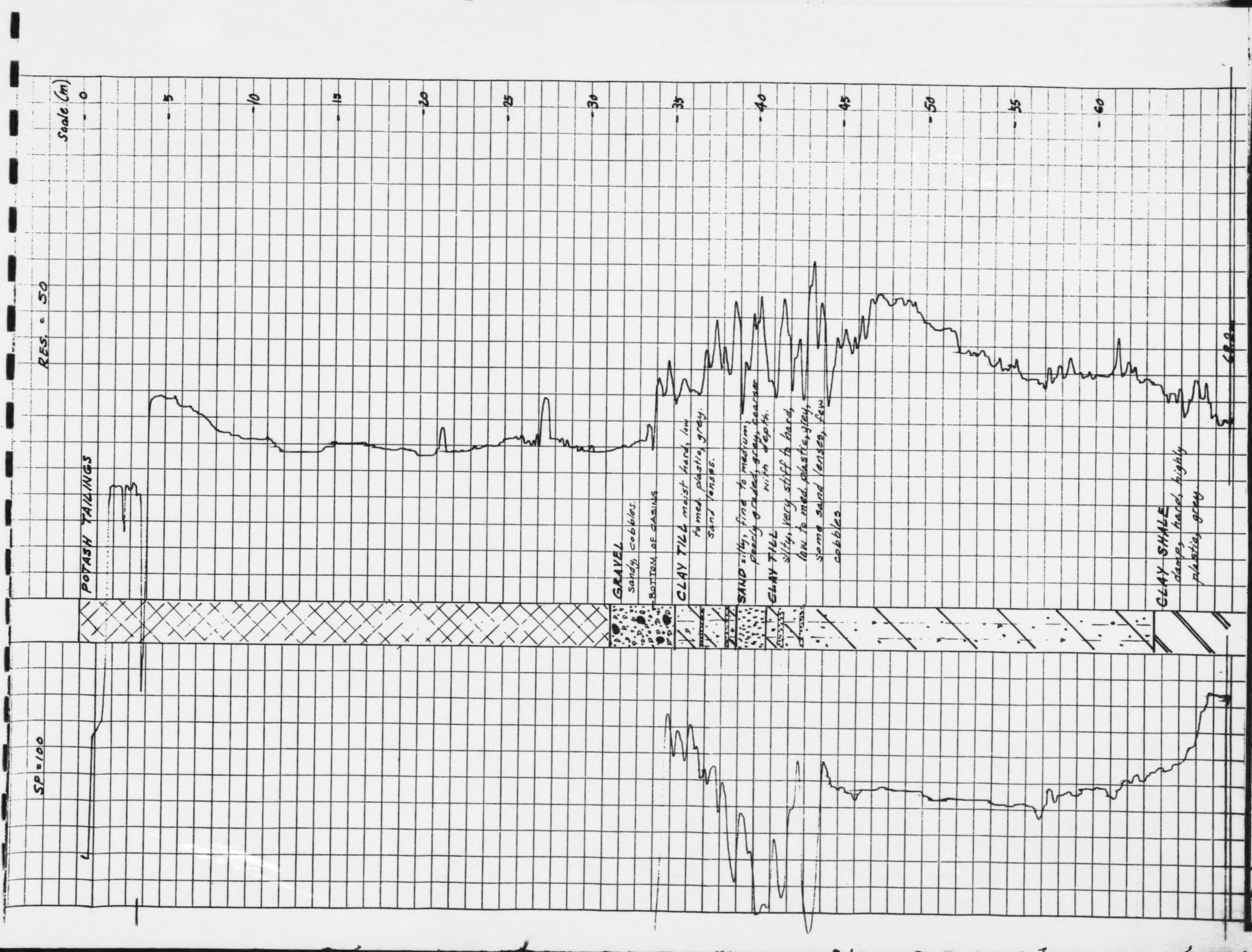
Tails Pile Instrumentation

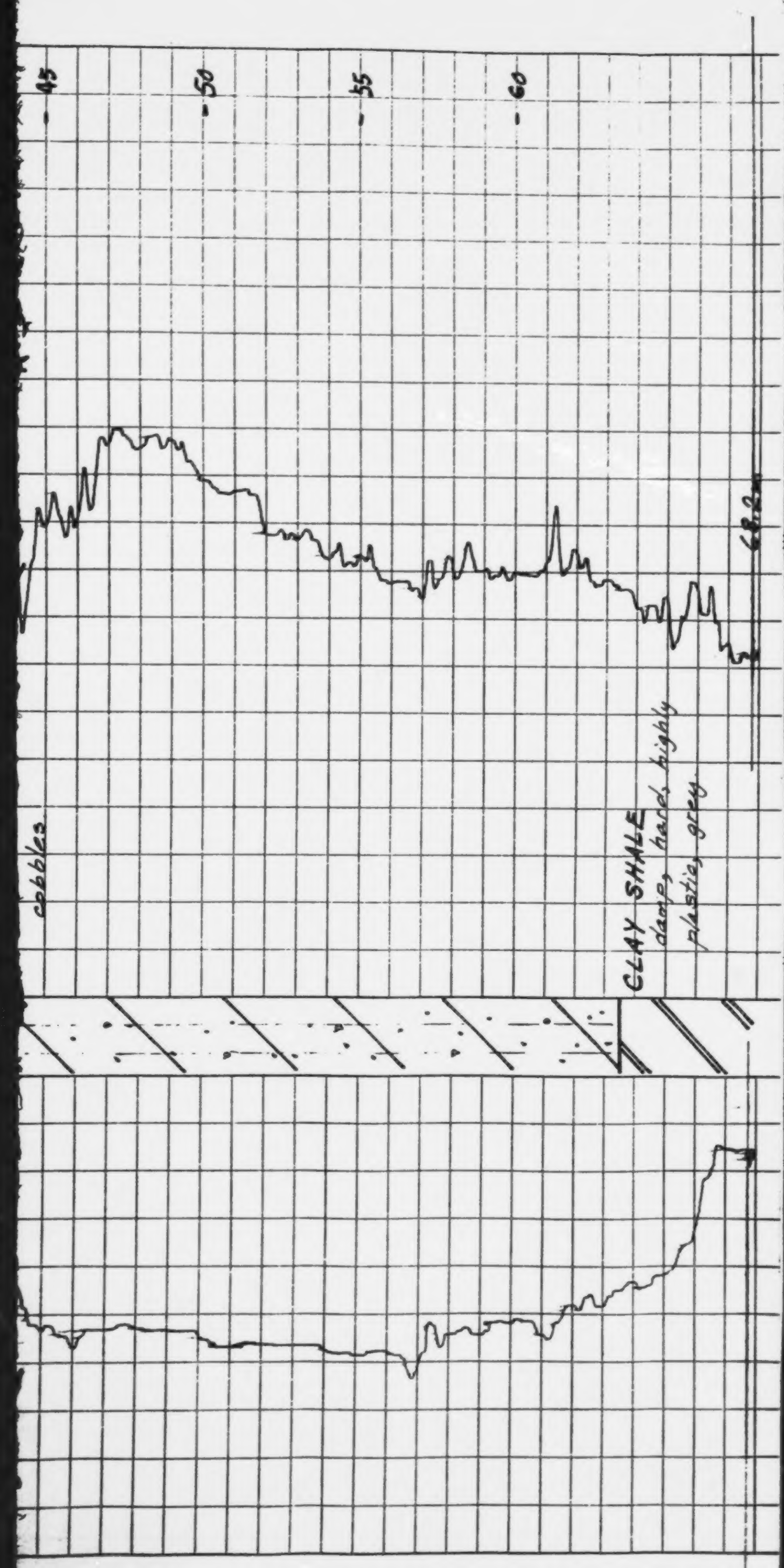
PCS ROCANVILLE

Scale: 1:240

Date Drilled MAY 3, 1985

DRAWING NO. S85-1774-2


Scale (m)
0
5
10
15
20
25
30
35
40
45
50
55
60
68.2
RES. = 50
SP = 100
POTASH TAILINGS
GRAVEL sandy, cobbles.
BOTTOM OF CASING
CLAY TILL moist hard, low to med. plastic, grey. sand lenses.
SAND silty, fine to medium, poorly graded, grey, coarser with depth.
CLAY TILL silty, very stiff to hard, low to med. plastic, grey, some sand lenses, few cobbles
CLAY SHALE damp, hard, highly plastic, grey.



TEST HOLE 85-68

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITION MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME

DRILLER: ______

LOGGER OPERATOR: DEL DOWNING

DEPTH DRILLED 67.8 m

DEPTH LOGGED 67.8 m

CONDUCTIVITY (µmhos/cm at 25°C)

DRILLING WATER ______

DRILLING FLUID 2696

DATE STARTED JULY 29/85

DATE COMPLETED MAY 8, 1985

DATE LOGGED JULY 29/85

NAME & MODEL OF LOGGER NIDCO/200

LOGGER S/N 1

BIT S/N ______

SPONTANEOUS POTENTIAL 100 millivolts/inch

SINGLE-POINT RESISTANCE 50 millivolts/inch

GRAVEL SAND SILT CLAY ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

Geotechnical Consultants Ltd.

ELECTRIC LOG

Tails Pile Instrumentation

PCS ROCANVILLE

Scale: 1: 200	DRAWING NO.
Date Drilled MAY 8 & JULY 26, 27, 28, /85	S85-1774-3

APPENDIX 2

Test Hole Logs and Details of Installations

APPENDIX 2

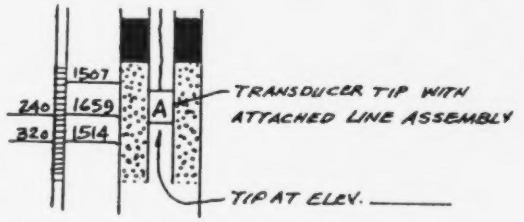
Test Hole Logs and Details of Installations

	Installation	Drawing No.
		Legend
Test Hole Log and Piezometer Detail	85-50 to 85-58 Inc. and 85-61 to 85-68 Inc.	S84-1776-4 to S84-1776-18

SAMPLE TYPE :

■ Shelby Tube
☒ Split Spoon
▨ Cuttings
▤ Core

TYPICAL 'A' TIP

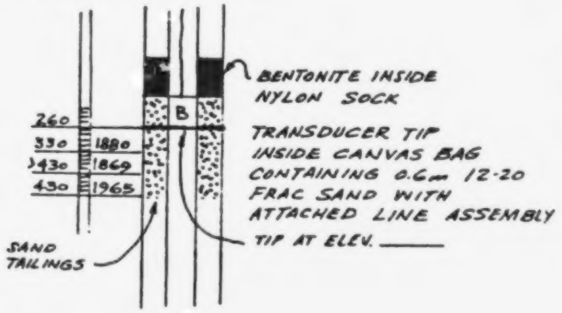

1507
240
1659
320
1514
A
TRANSDUCER TIP WITH ATTACHED LINE ASSEMBLY
TIP AT ELEV. ______

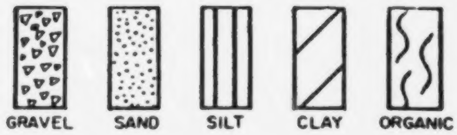
THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

LEGEND :

γ_D — DRY DENSITY (kg/m^3)
W% — WATER CONTENT (% OF DRY SOIL WEIGHT)
L_w — LIQUID LIMIT
P_w — PLASTIC LIMIT
U — UNCONFINED COMPRESSIVE STRENGTH (kPa)
PP — POCKET PENETROMETER (kPa)
SO_4 — SULPHATE CONTENT (% OF DRY SOIL WEIGHT)
✱ — SULPHATE CONTENT OF WATER SAMPLE (PARTS PER MILLION)
▼ — RECORDED WATER LEVEL
TR — TRACE
N — STANDARD PENETRATION TEST (CSA A119.1-60)

TYPICAL 'B' TIP


BENTONITE INSIDE NYLON SOCK
B
260
330
1880
430
1869
430
1965
TRANSDUCER TIP INSIDE CANVAS BAG CONTAINING 0.6m 12-20 FRAC SAND WITH ATTACHED LINE ASSEMBLY
TIP AT ELEV. ______
SAND TAILINGS


GRAVEL
SAND
SILT
CLAY
ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

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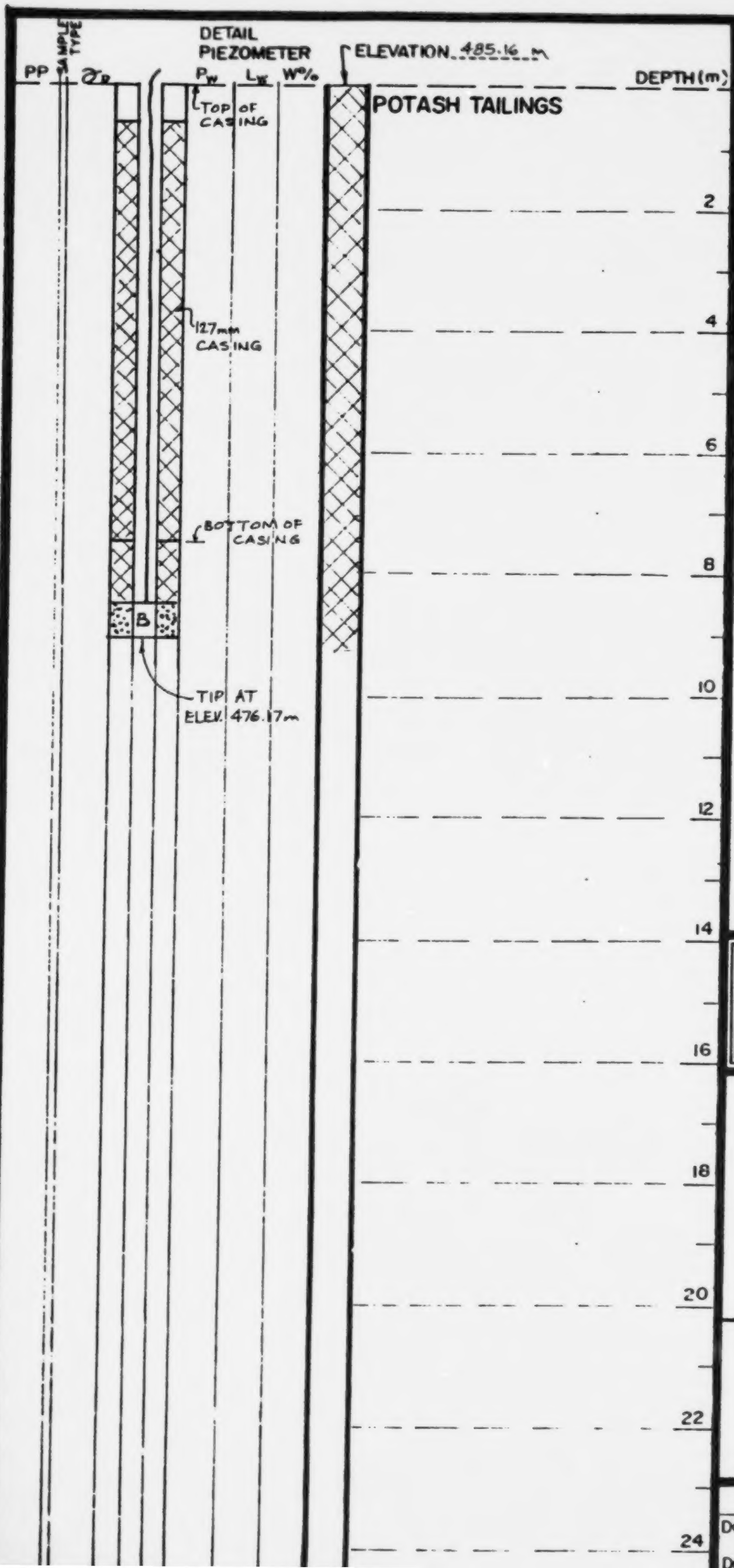
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile
Instrumentation
PCS ROCANVILLE

LEGEND


PP
SAMPLE TYPE
γ_D
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 485.16 m
DEPTH (m)
POTASH TAILINGS
TOP OF CASING
127mm CASING
BOTTOM OF CASING
B
TIP AT ELEV. 476.17 m
2
4
6
8
10
12
14
16
18
20
22
24

TEST HOLE 85-50

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250

LEGEND:

- " DIA. SCREEN
- BENTONITE SEAL
- CEMENT GROUT
- " DIA. PVC PIPE
- POTASH TAILS
- FRAC SAND
- ← CUTTINGS SAMPLE

GRAVEL SAND SILT CLAY ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

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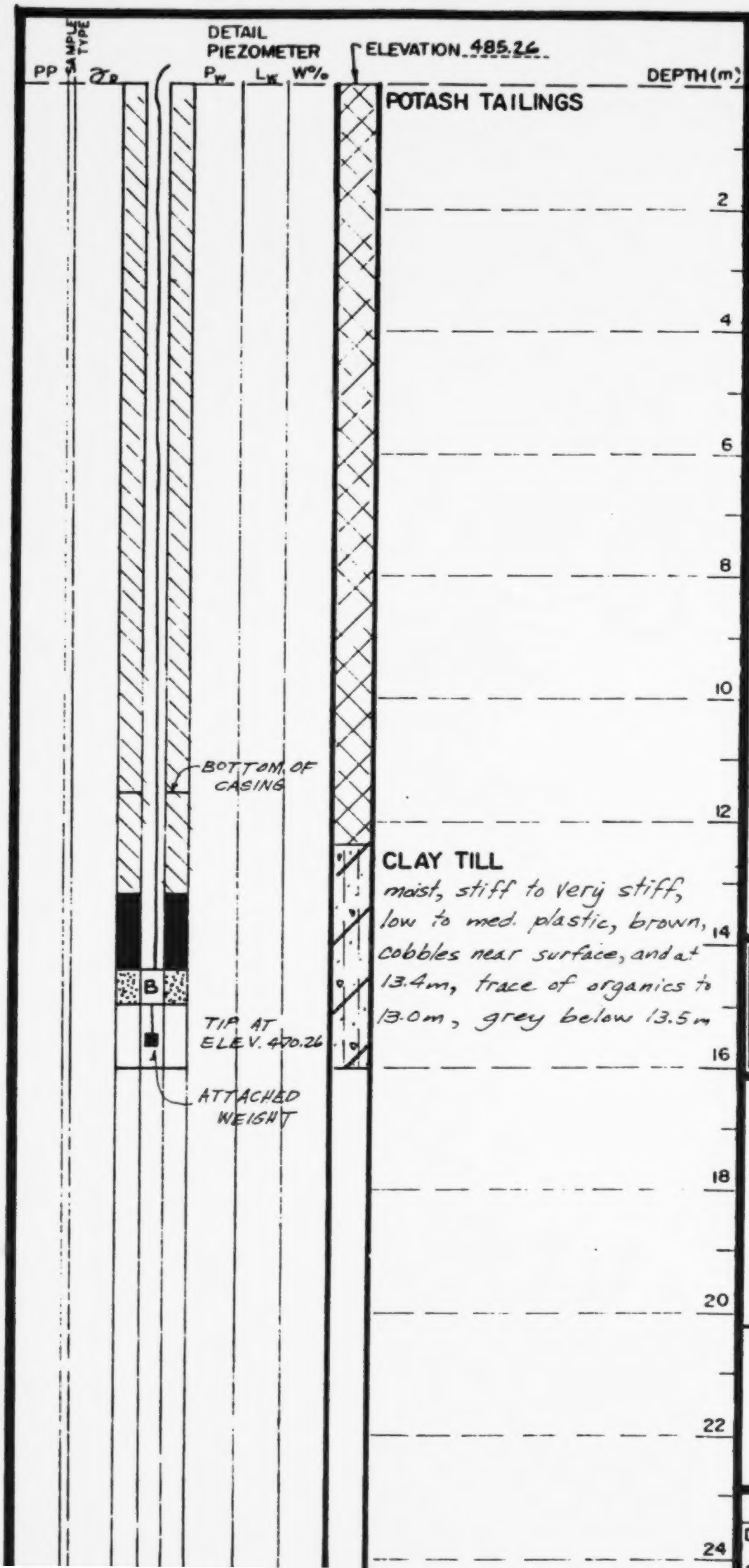
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100	DRAWING NUMBER:
Date Drilled: MAY 8/85 Date Installed:	S85-1774-4


PP
SAMPLE TYPE
γ_D
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 485.26
DEPTH (m)
2
4
6
8
10
BOTTOM OF CASING
12
B
14
TIP AT ELEV. 470.26
16
ATTACHED WEIGHT
18
20
22
24

POTASH TAILINGS

CLAY TILL

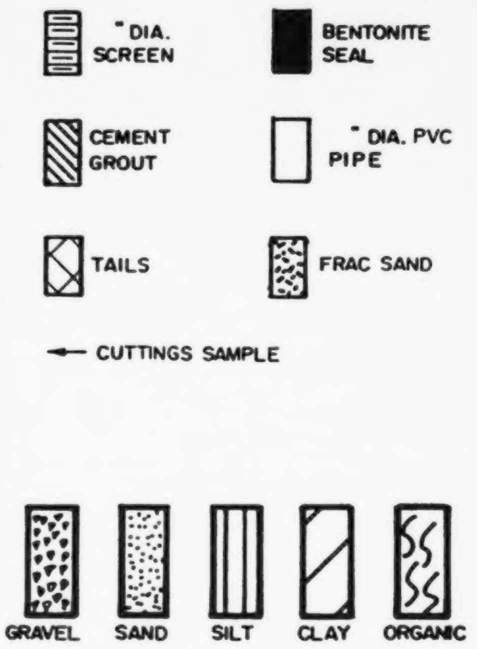
moist, stiff to very stiff, low to med. plastic, brown, cobbles near surface, and at 13.4m, trace of organics to 13.0m, grey below 13.5m

TEST HOLE 85-51

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250

LEGEND:


" DIA. SCREEN
BENTONITE SEAL
CEMENT GROUT
" DIA. PVC PIPE
TAILS
FRAC SAND
CUTTINGS SAMPLE
GRAVEL
SAND
SILT
CLAY
ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

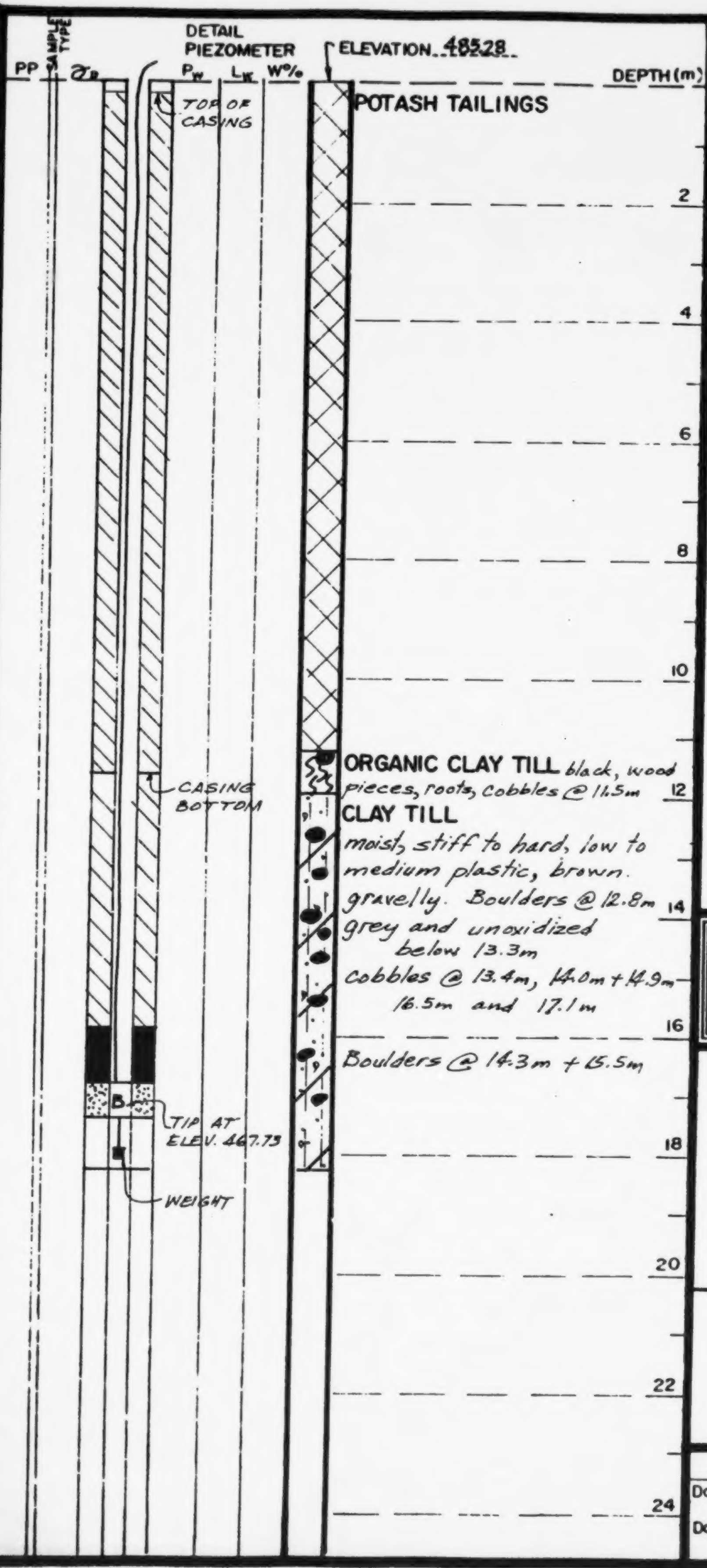
Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100

Date Drilled:
MAY 8/85

DRAWING NUMBER:
S85-1774-5


PP
SAMPLE TYPE
τ_v
DETAIL
PIEZOMETER
P_W
L_W
W%
ELEVATION 48528
DEPTH (m)
TOP OF CASING
CASING BOTTOM
B
TIP AT ELEV. 467.73
WEIGHT
2
4
6
8
10
12
14
16
18
20
22
24

POTASH TAILINGS

ORGANIC CLAY TILL black, wood pieces, roots, cobbles @ 11.5m

CLAY TILL

moist, stiff to hard, low to medium plastic, brown. gravelly. Boulders @ 12.8m grey and unoxidized below 13.3m

cobbles @ 13.4m, 14.0m + 14.9m 16.5m and 17.1m

Boulders @ 14.3m + 15.5m

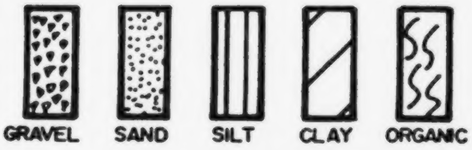
TEST HOLE 85-52

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250

LEGEND:

▤ " DIA. SCREEN
■ BENTONITE SEAL
▨ CEMENT GROUT
□ " DIA. PVC PIPE
⊠ TAILS
▒ FRAC SAND
← CUTTINGS SAMPLE


GRAVEL
SAND
SILT
CLAY
ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100

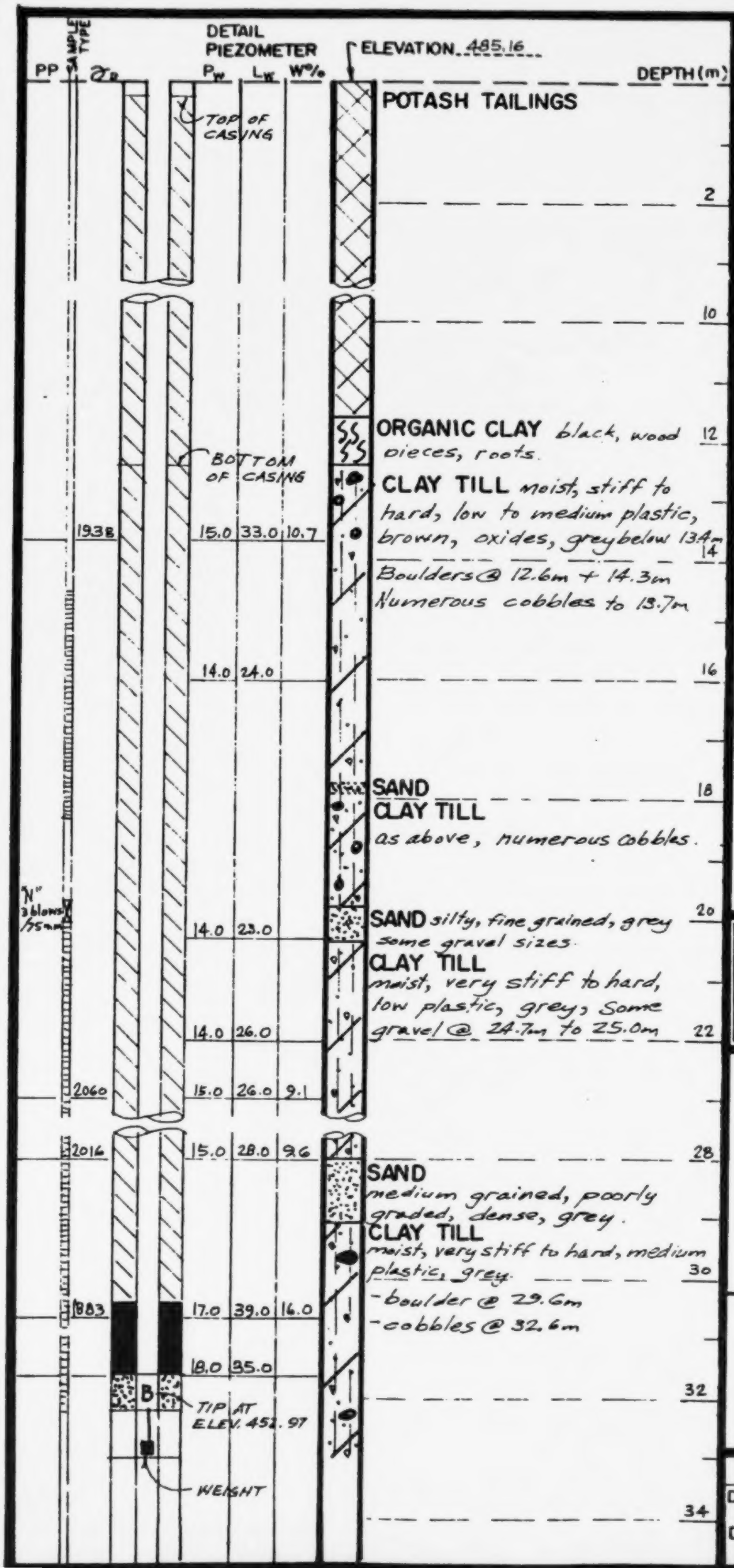
Date Drilled: MAY 8/85
Date Installed: MAY 8/85

DRAWING NUMBER:
S85-1774-6

TEST HOLE 85-53

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250



PP	SAMPLE TYPE	γ_D	P_W	L_W	W%
		1938	15.0	33.0	10.7
			14.0	24.0	
"N" 3 blows /75mm			14.0	23.0	
			14.0	26.0	
		2060	15.0	26.0	9.1
		2016	15.0	28.0	9.6
		1883	17.0	39.0	16.0
			18.0	35.0	

POTASH TAILINGS

ORGANIC CLAY black, wood pieces, roots.

CLAY TILL moist, stiff to hard, low to medium plastic, brown, oxides, grey below 13.4m

Boulders @ 12.6m + 14.3m
Numerous cobbles to 13.7m

SAND

CLAY TILL
as above, numerous cobbles.

SAND silty, fine grained, grey some gravel sizes.

CLAY TILL
moist, very stiff to hard, low plastic, grey, Some gravel @ 24.7m to 25.0m

SAND
medium grained, poorly graded, dense, grey.

CLAY TILL
moist, very stiff to hard, medium plastic, grey.
-boulder @ 29.6m
-cobbles @ 32.6m

LEGEND:

- ▤ " DIA. SCREEN
- ■ BENTONITE SEAL
- ▨ CEMENT GROUT
- ☐ " DIA. PVC PIPE
- ☒ TAILS
- ▒ FRAC SAND
- ← CUTTINGS SAMPLE

GRAVEL	SAND	SILT	CLAY	ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

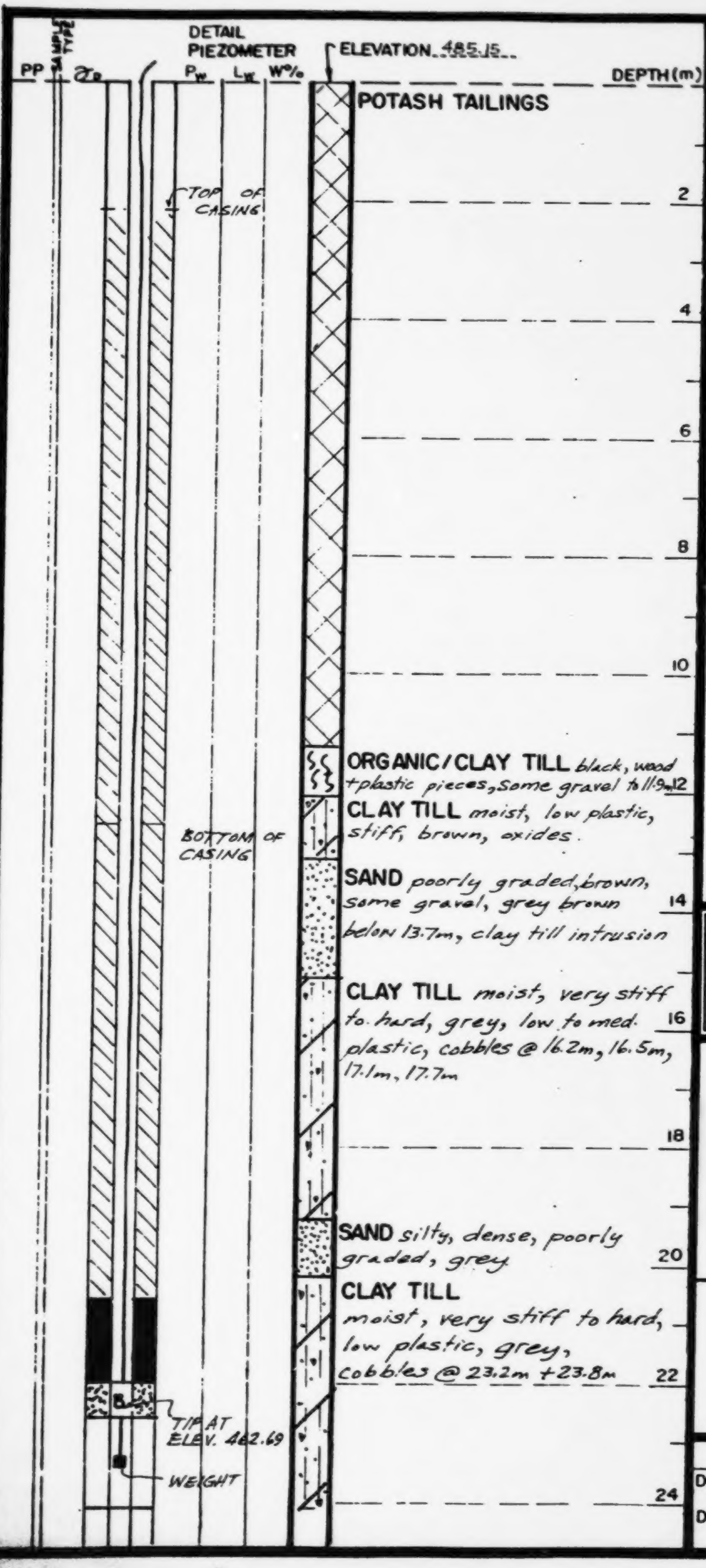
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100
Date Drilled: MAY 6/85
Date Installed: MAY 6/85

DRAWING NUMBER: S85-1774-7


PP
SAMPLE TYPE
σv
DETAIL PIEZOMETER
Pw
Lw
W%
ELEVATION 485.15
DEPTH (m)
2
4
6
8
10
12
14
16
18
20
22
24
TOP OF CASING
BOTTOM OF CASING
B
TIP AT ELEV. 462.69
WEIGHT

POTASH TAILINGS

ORGANIC/CLAY TILL *black, wood +plastic pieces, Some gravel to 11.9m*

CLAY TILL *moist, low plastic, stiff, brown, oxides.*

SAND *poorly graded, brown, some gravel, grey brown below 13.7m, clay till intrusion*

CLAY TILL *moist, very stiff to hard, grey, low to med. plastic, cobbles @ 16.2m, 16.5m, 17.1m, 17.7m*

SAND *silty, dense, poorly graded, grey*

CLAY TILL
moist, very stiff to hard, low plastic, grey, cobbles @ 23.2m + 23.8m

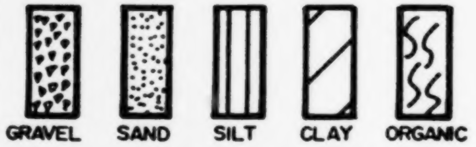
TEST HOLE 85-54

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250

LEGEND:

▤ " DIA. SCREEN
■ BENTONITE SEAL
▨ CEMENT GROUT
□ " DIA. PVC PIPE
⊠ TAILS
⁙ FRAC SAND
← CUTTINGS SAMPLE


GRAVEL
SAND
SILT
CLAY
ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

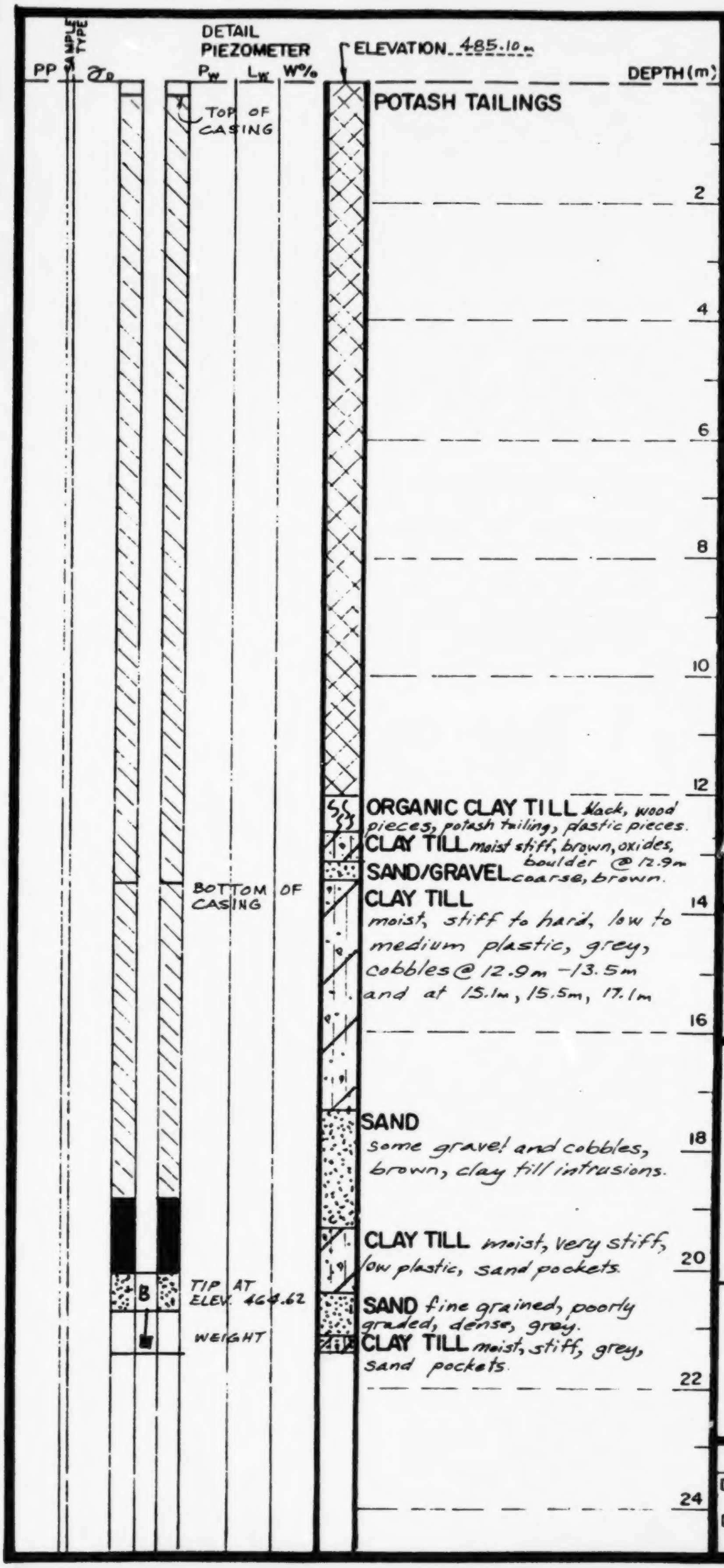
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100
Date Drilled: MAY 7/85
Date Installed: MAY 7/85

DRAWING NUMBER: S85-1774-8


PP
SAMPLE TYPE
γ_D
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 485.10 m
DEPTH (m)
TOP OF CASING
BOTTOM OF CASING
TIP AT ELEV. 464.62
B
WEIGHT
2
4
6
8
10
12
14
16
18
20
22
24

POTASH TAILINGS

ORGANIC CLAY TILL black, wood pieces, potash tailing, plastic pieces.

CLAY TILL moist stiff, brown, oxides, boulder @ 12.9m

SAND/GRAVEL coarse, brown.

CLAY TILL moist, stiff to hard, low to medium plastic, grey, cobbles @ 12.9m -13.5m and at 15.1m, 15.5m, 17.1m

SAND some gravel and cobbles, brown, clay till intrusions.

CLAY TILL moist, very stiff, low plastic, sand pockets.

SAND fine grained, poorly graded, dense, grey.

CLAY TILL moist, stiff, grey, sand pockets.

TEST HOLE 85-55

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250

LEGEND:

▤ " DIA. SCREEN
■ BENTONITE SEAL
▨ CEMENT GROUT
☐ " DIA. PVC PIPE
☒ TAILS
▩ FRAC SAND
← CUTTINGS SAMPLE

GRAVEL
SAND
SILT
CLAY
ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

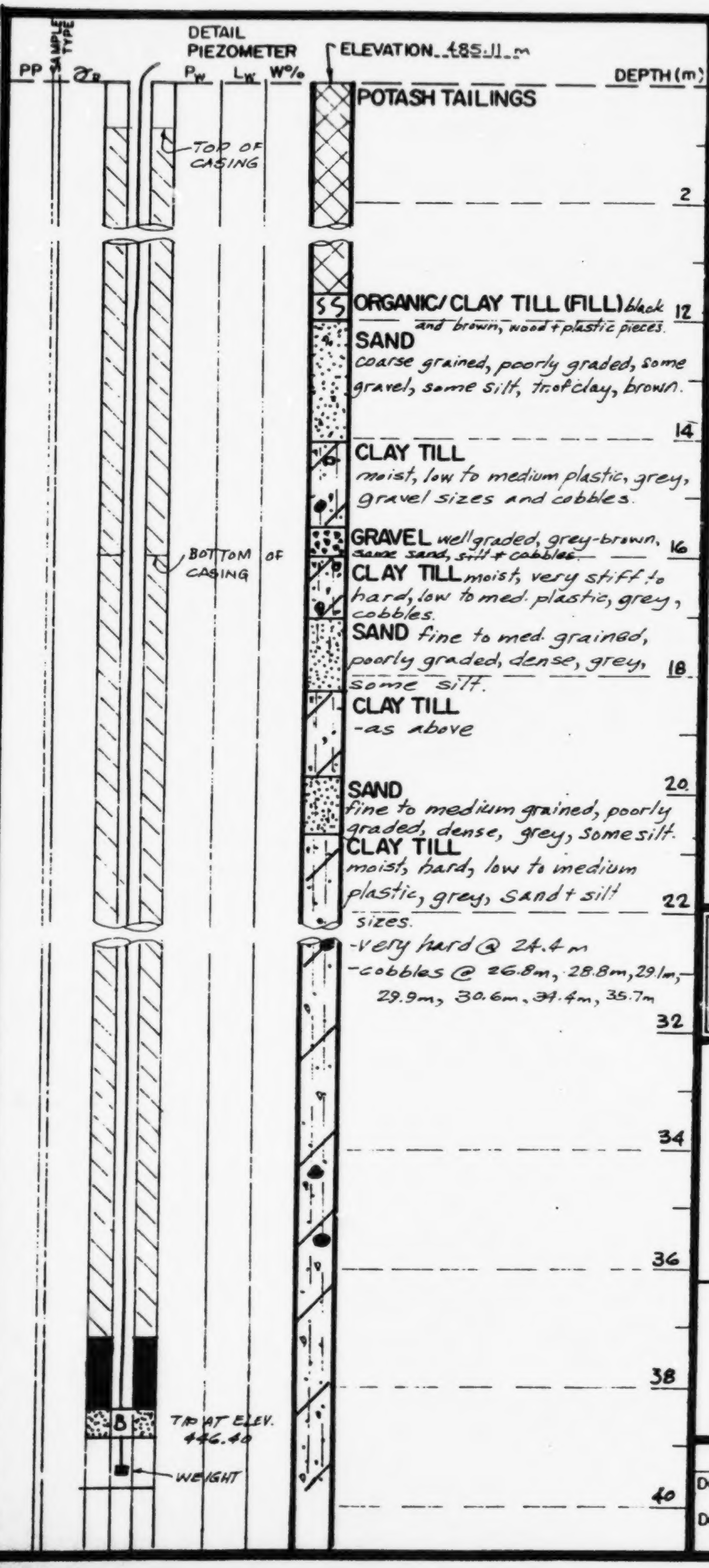
Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100

Date Drilled: MAY 6/85
Date Installed: MAY 6/85

DRAWING NUMBER: S85-1774-9


PP
SAMPLE TYPE
γ_B
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 485.11 m
DEPTH (m)
TOP OF CASING
BOTTOM OF CASING
TIP AT ELEV. 446.40
B
WEIGHT
2
12
14
16
18
20
22
32
34
36
38
40

POTASH TAILINGS

ORGANIC/CLAY TILL (FILL) black and brown, wood + plastic pieces.

SAND
coarse grained, poorly graded, some gravel, some silt, tr. of clay, brown.

CLAY TILL
moist, low to medium plastic, grey, gravel sizes and cobbles.

GRAVEL well graded, grey-brown, some sand, silt + cobbles.

CLAY TILL moist, very stiff to hard, low to med. plastic, grey, cobbles.

SAND fine to med. grained, poorly graded, dense, grey, some silt.

CLAY TILL
-as above

SAND
fine to medium grained, poorly graded, dense, grey, some silt.

CLAY TILL
moist, hard, low to medium plastic, grey, sand + silt sizes.
-very hard @ 24.4 m
-cobbles @ 26.8m, 28.8m, 29.1m, 29.9m, 30.6m, 34.4m, 35.7m

TEST HOLE 85-56

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250

LEGEND:

▤ " DIA. SCREEN
■ BENTONITE SEAL
▨ CEMENT GROUT
□ " DIA. PVC PIPE
☒ TAILS
░ FRAC SAND
← CUTTINGS SAMPLE

GRAVEL
SAND
SILT
CLAY
ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

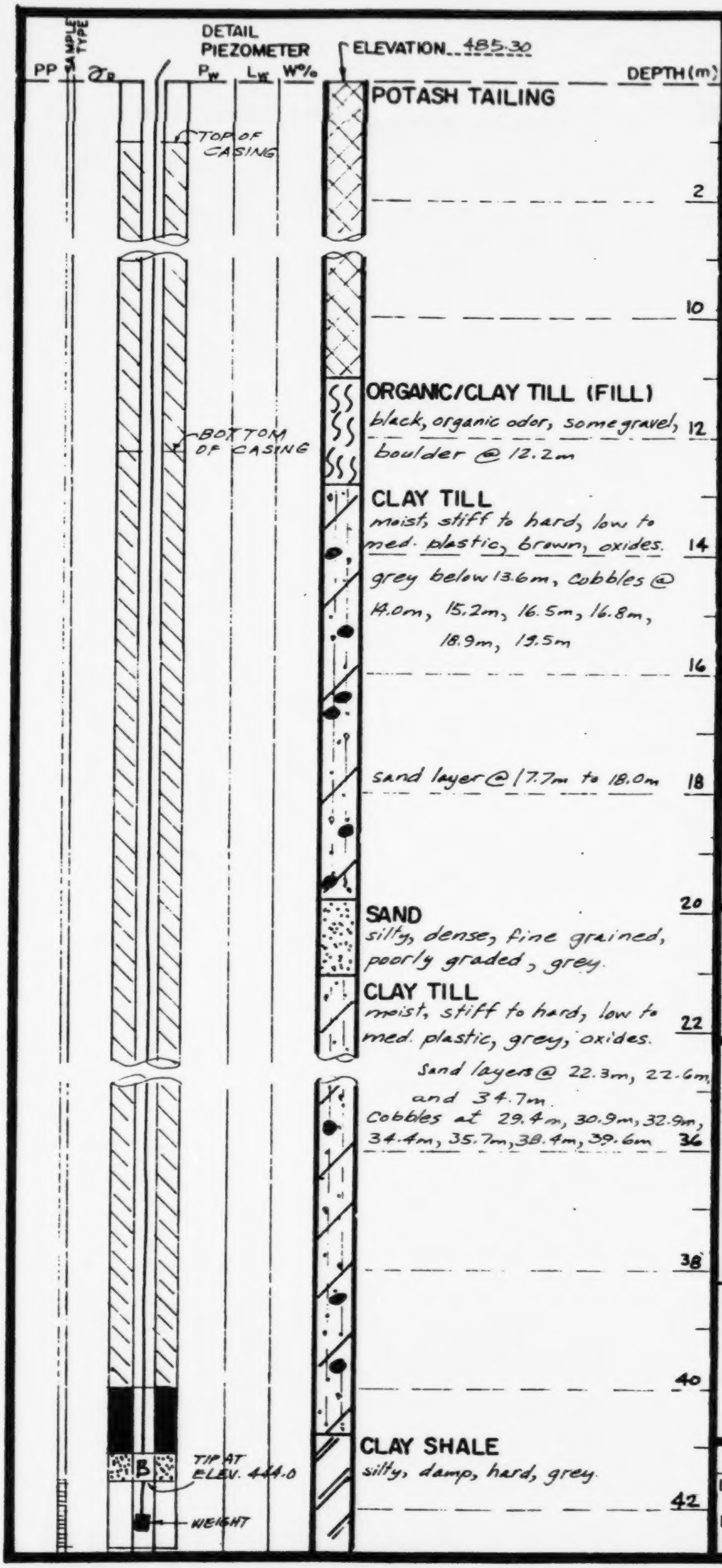
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100
Date Drilled: MAY 6/85
Date Installed: MAY 6/85

DRAWING NUMBER: S85-1774-10


PP
SAMPLE TYPE
γ_D
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 485.30
DEPTH (m)
TOP OF CASING
BOTTOM OF CASING
B
TIP AT ELEV. 444.0
WEIGHT
2
10
12
14
16
18
20
22
36
38
40
42

POTASH TAILING

ORGANIC/CLAY TILL (FILL)
black, organic odor, some gravel, boulder @ 12.2m

CLAY TILL
moist, stiff to hard, low to med. plastic, brown, oxides.
grey below 13.6m, Cobbles @ 14.0m, 15.2m, 16.5m, 16.8m, 18.9m, 19.5m

sand layer @ 17.7m to 18.0m

SAND
silty, dense, fine grained, poorly graded, grey.

CLAY TILL
moist, stiff to hard, low to med. plastic, grey, oxides.
Sand layers @ 22.3m, 22.6m, and 34.7m.
Cobbles at 29.4m, 30.9m, 32.9m, 34.4m, 35.7m, 38.4m, 39.6m

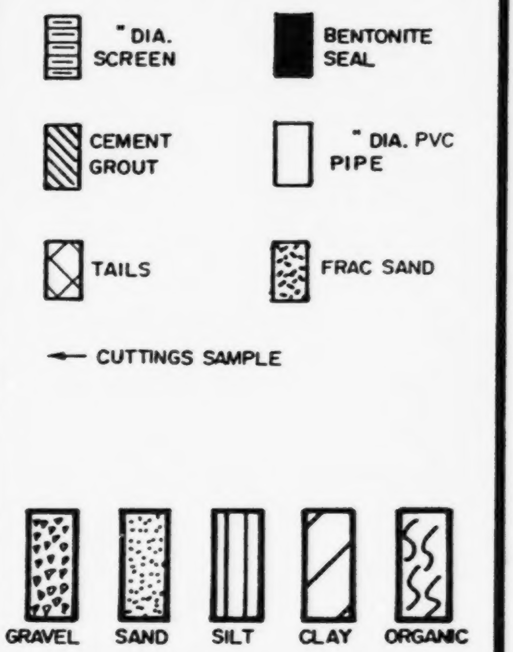
CLAY SHALE
silty, damp, hard, grey.

TEST HOLE 85-57

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250

LEGEND:


" DIA. SCREEN
BENTONITE SEAL
CEMENT GROUT
" DIA. PVC PIPE
TAILS
FRAC SAND
CUTTINGS SAMPLE
GRAVEL
SAND
SILT
CLAY
ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

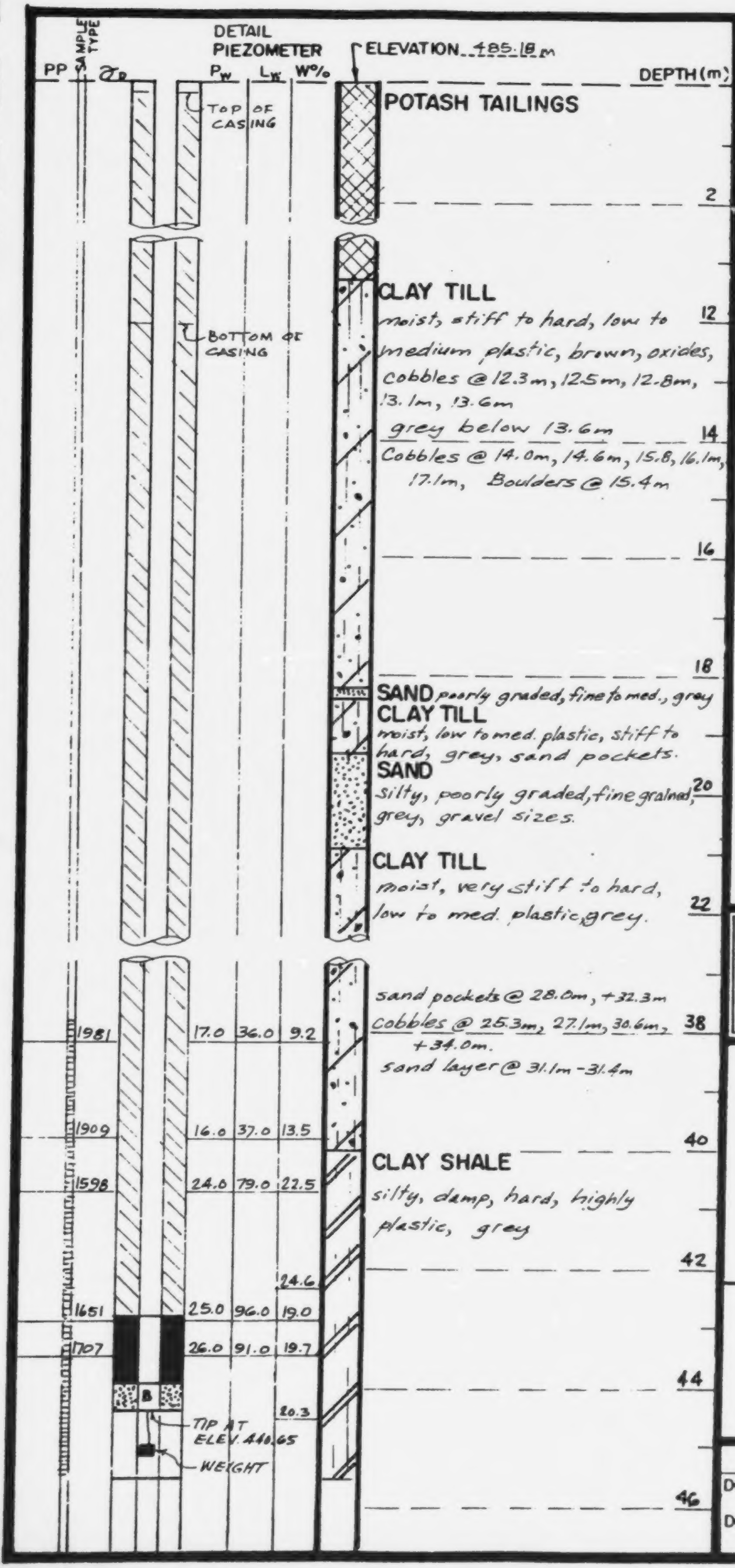
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100
Date Drilled: APRIL 30/85
Date Installed: APRIL 30/85

DRAWING NUMBER: S85-1774-11


PP
SAMPLE TYPE
τ_D
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 485.18 m
DEPTH (m)
TOP OF CASING
BOTTOM OF CASING
2
12
14
16
18
20
22
38
40
42
44
46
1981
17.0
36.0
9.2
1909
16.0
37.0
13.5
1598
24.0
79.0
22.5
24.6
1651
25.0
96.0
19.0
1707
26.0
91.0
19.7
B
20.3
TIP AT ELEV. 440.65
WEIGHT

POTASH TAILINGS

CLAY TILL
moist, stiff to hard, low to medium plastic, brown, oxides, cobbles @ 12.3m, 12.5m, 12.8m, 13.1m, 13.6m
grey below 13.6m
Cobbles @ 14.0m, 14.6m, 15.8, 16.1m, 17.1m, Boulders @ 15.4m

SAND poorly graded, fine to med., grey

CLAY TILL
moist, low to med. plastic, stiff to hard, grey, sand pockets.

SAND
silty, poorly graded, fine grained, grey, gravel sizes.

CLAY TILL
moist, very stiff to hard, low to med. plastic, grey.

sand pockets @ 28.0m, + 32.3m
cobbles @ 25.3m, 27.1m, 30.6m, + 34.0m.
sand layer @ 31.1m - 31.4m

CLAY SHALE
silty, damp, hard, highly plastic, grey

TEST HOLE 85-58

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY MODEL 1250

LEGEND:

▤ " DIA. SCREEN	■ BENTONITE SEAL
▧ CEMENT GROUT	☐ " DIA. PVC PIPE
⊠ TAILS	▒ FRAC SAND
← CUTTINGS SAMPLE	

GRAVEL SAND SILT CLAY ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

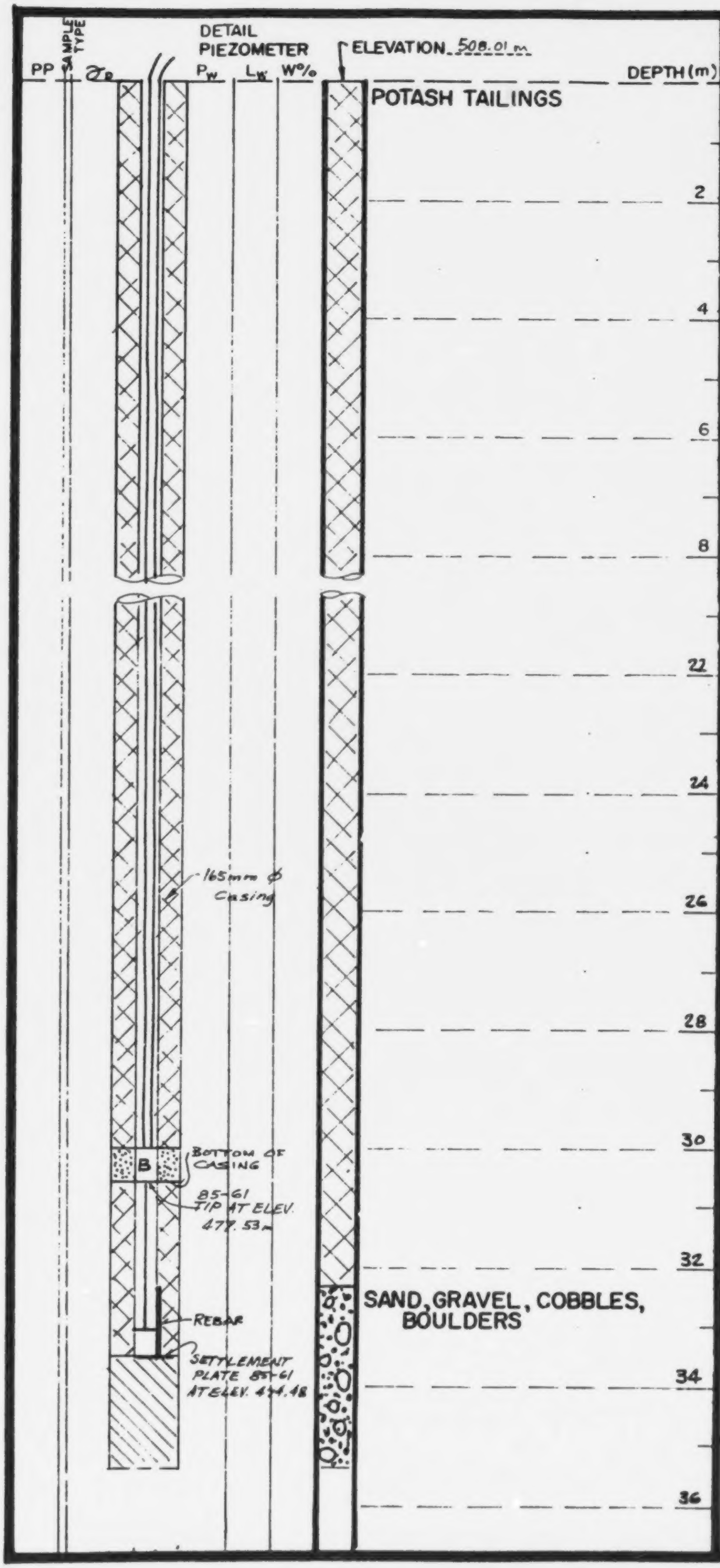
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100
Date Drilled: MAY 3/85
Date Installed: MAY 3/85

DRAWING NUMBER: S85-1774-12


PP
SAMPLE TYPE
γ_D
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 508.01 m
DEPTH (m)
POTASH TAILINGS
2
4
6
8
22
24
-165mm ϕ Casing
26
28
30
BOTTOM OF CASING
B
85-61 TIP AT ELEV. 477.53 m
32
SAND, GRAVEL, COBBLES, BOULDERS
REBAR
SETTLEMENT PLATE 85-61 AT ELEV. 474.48
34
36

TEST HOLE 85-61

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY MODEL 1250

LEGEND:

▤	" DIA. SCREEN	■	BENTONITE SEAL
▨	CEMENT GROUT	▯	" DIA. PVC PIPE
⊠	TAILS	▒	FRAC SAND

← CUTTINGS SAMPLE

GRAVEL	SAND	SILT	CLAY	ORGANIC
▓	▒	▥	▧	§

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100

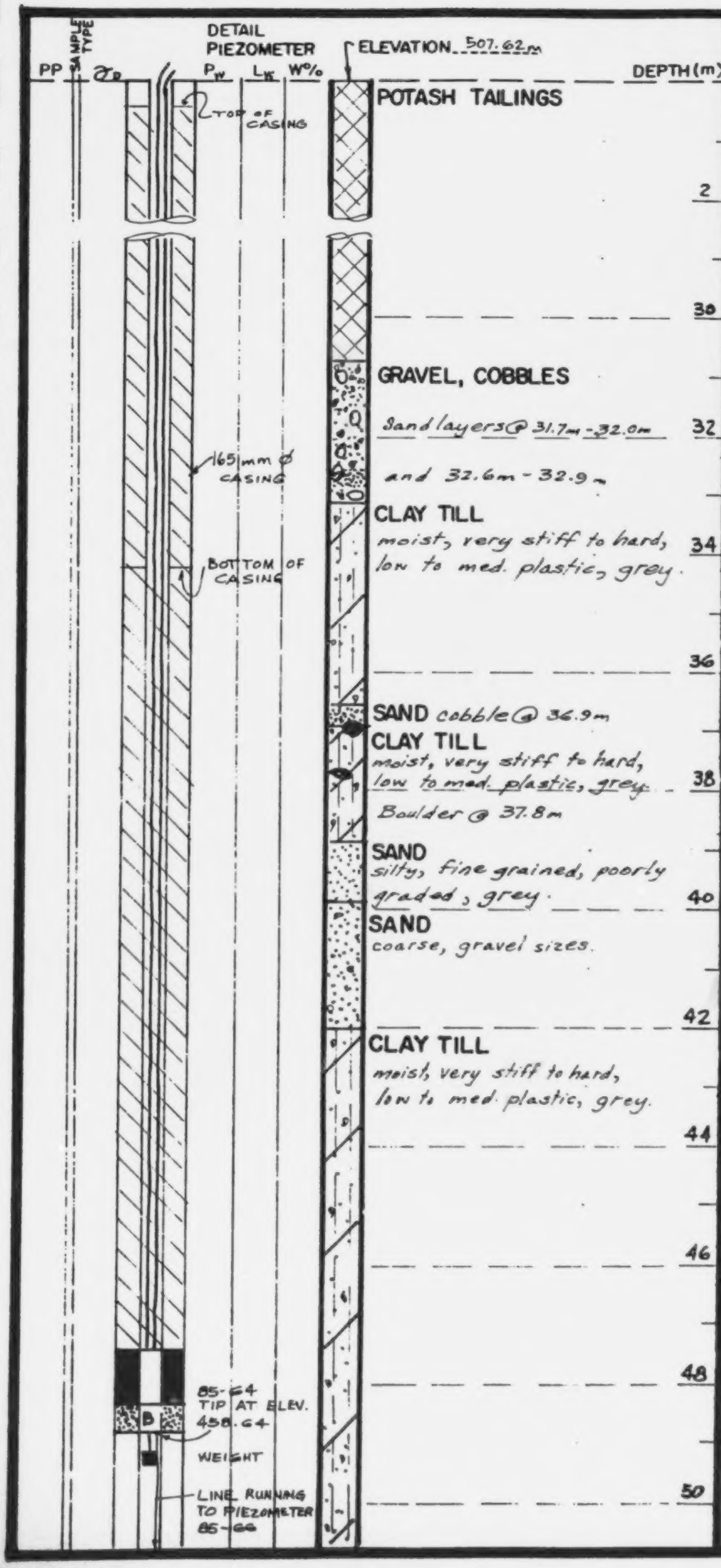
Date Drilled: AUG. 9/85
Date Installed: AUG. 9/85

DRAWING NUMBER: S85-1774-13

TEST HOLE 85- 66

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY MODEL 1250


PP
SAMPLE TYPE
γ_D
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 507.62 m
DEPTH (m)
TOP OF CASING
165 mm ⌀ CASING
BOTTOM OF CASING
85-64 TIP AT ELEV. 458.64
B
WEIGHT
LINE RUNNING TO PIEZOMETER 85-66
2
30
32
34
36
38
40
42
44
46
48
50

POTASH TAILINGS

GRAVEL, COBBLES
Sand layers @ 31.7m - 32.0m and 32.6m - 32.9m

CLAY TILL
moist, very stiff to hard, low to med. plastic, grey.

SAND *cobble @ 36.9m*

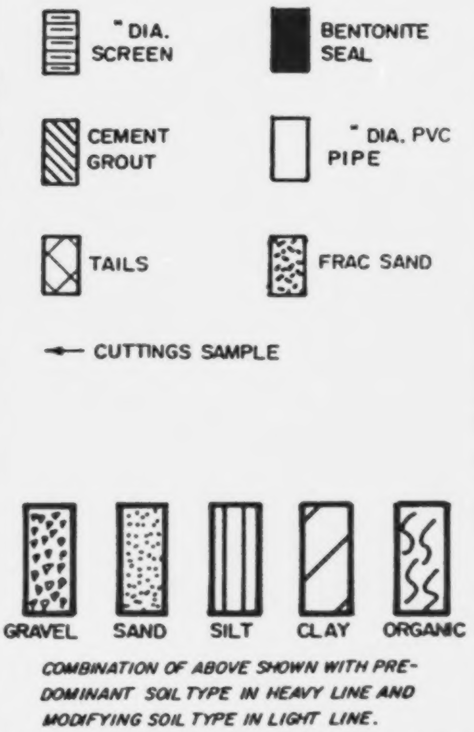
CLAY TILL
moist, very stiff to hard, low to med. plastic, grey.
Boulder @ 37.8m

SAND
silty, fine grained, poorly graded, grey.

SAND
coarse, gravel sizes.

CLAY TILL
moist, very stiff to hard, low to med. plastic, grey.

LEGEND:


" DIA. SCREEN
BENTONITE SEAL
CEMENT GROUT
" DIA. PVC PIPE
TAILS
FRAC SAND
← CUTTINGS SAMPLE
GRAVEL
SAND
SILT
CLAY
ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

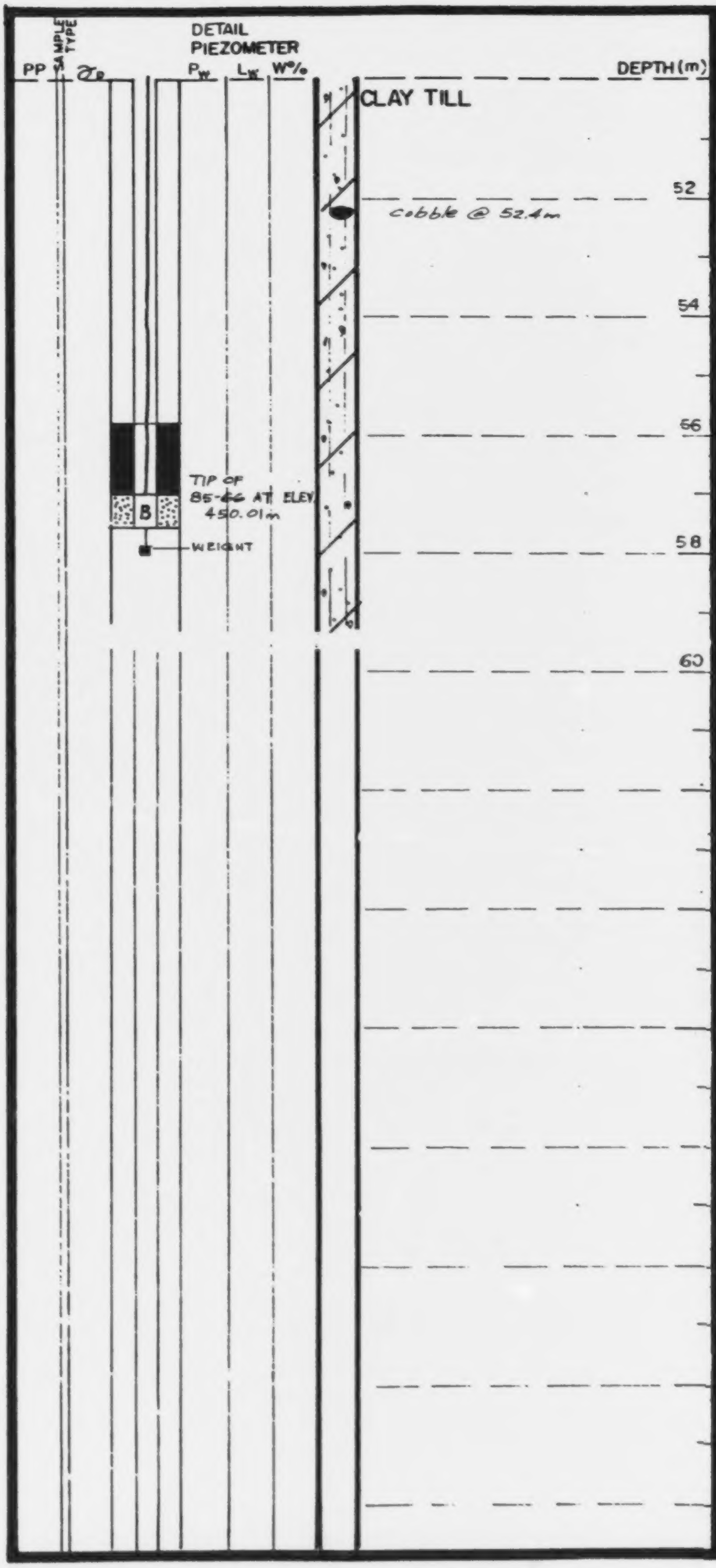
TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100

Date Drilled: *JULY 31/AUG 1/AUG. 7,8/85*

Date Installed: *AUG. 8,9/85*

DRAWING NUMBER: S85-1774-14


PP
SAMPLE TYPE
σ_p
DETAIL PIEZOMETER
P_W
L_W
W%
DEPTH (m)
CLAY TILL
52
cobble @ 52.4m
54
56
TIP OF 85-66 AT ELEV. 450.01m
B
WEIGHT
58
60

TEST HOLE 85-66

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250

LEGEND:

▤ " DIA. SCREEN
■ BENTONITE SEAL
▧ CEMENT GROUT
□ " DIA. PVC PIPE
☒ TAILS
▒ FRAC SAND
← CUTTINGS SAMPLE

GRAVEL SAND SILT CLAY ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

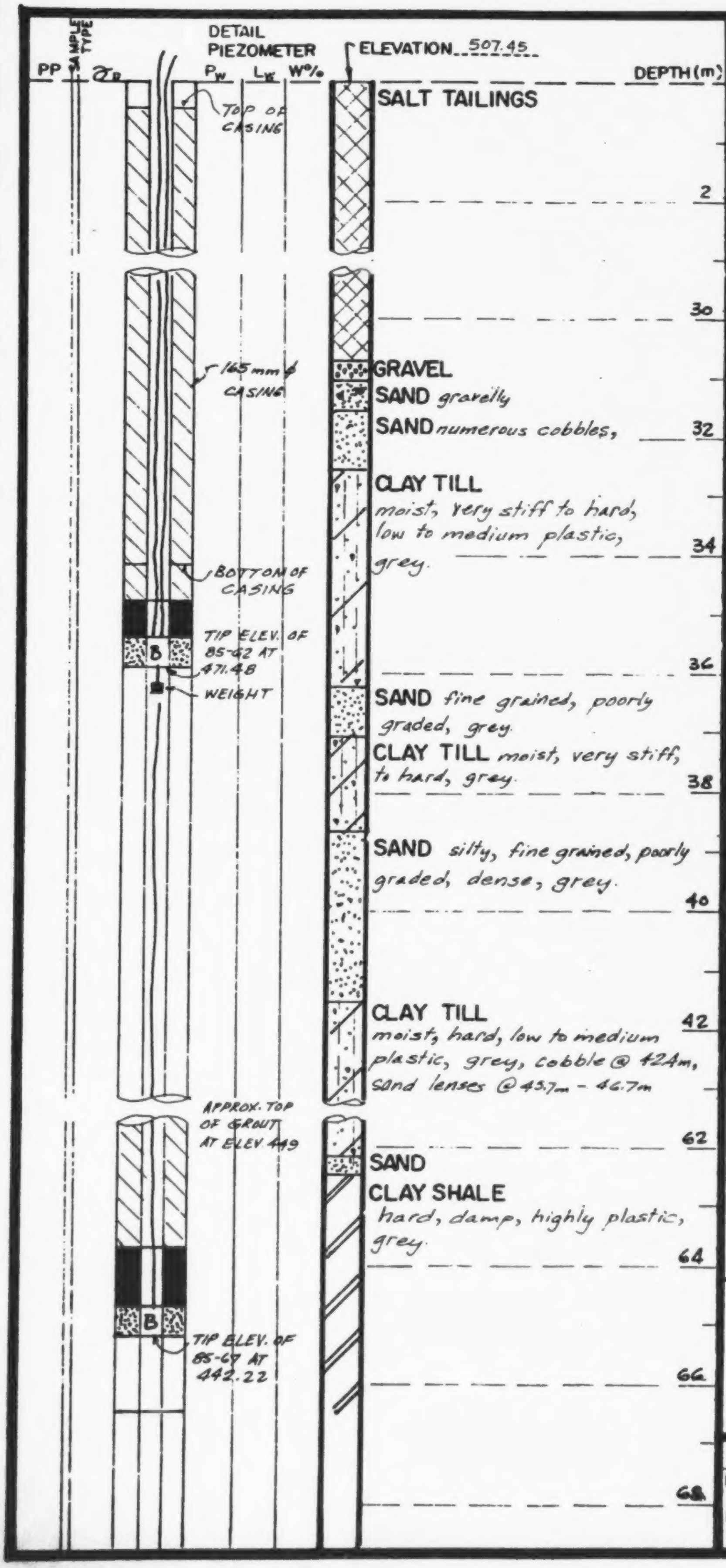
SCALE 1:100
Date Drilled:
JULY 31/AUG. 1/AUG 7,8/85
Date Installed:
AUG 8,9/85

DRAWING NUMBER:
S85-1774-15

TEST HOLE 85-67

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250


PP
SAMPLE TYPE
σ_D
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 507.45
DEPTH (m)
TOP OF CASING
2
30
165 mm ϕ CASING
32
34
BOTTOM OF CASING
TIP ELEV. OF 85-62 AT 471.48
B
WEIGHT
36
38
40
42
APPROX. TOP OF GROUT AT ELEV. 449
62
64
B
TIP ELEV. OF 85-67 AT 442.22
66
68

SALT TAILINGS

GRAVEL

SAND *gravelly*

SAND *numerous cobbles,*

CLAY TILL
moist, very stiff to hard, low to medium plastic, grey.

SAND *fine grained, poorly graded, grey.*

CLAY TILL *moist, very stiff, to hard, grey.*

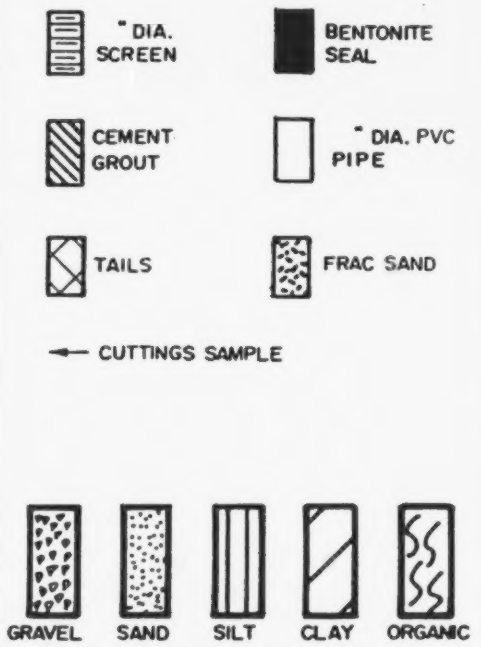
SAND *silty, fine grained, poorly graded, dense, grey.*

CLAY TILL
moist, hard, low to medium plastic, grey, cobble @ 42.4m, sand lenses @ 43.7m - 46.7m

SAND

CLAY SHALE
hard, damp, highly plastic, grey.

LEGEND:


" DIA. SCREEN
BENTONITE SEAL
CEMENT GROUT
" DIA. PVC PIPE
TAILS
FRAC SAND
← CUTTINGS SAMPLE
GRAVEL
SAND
SILT
CLAY
ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

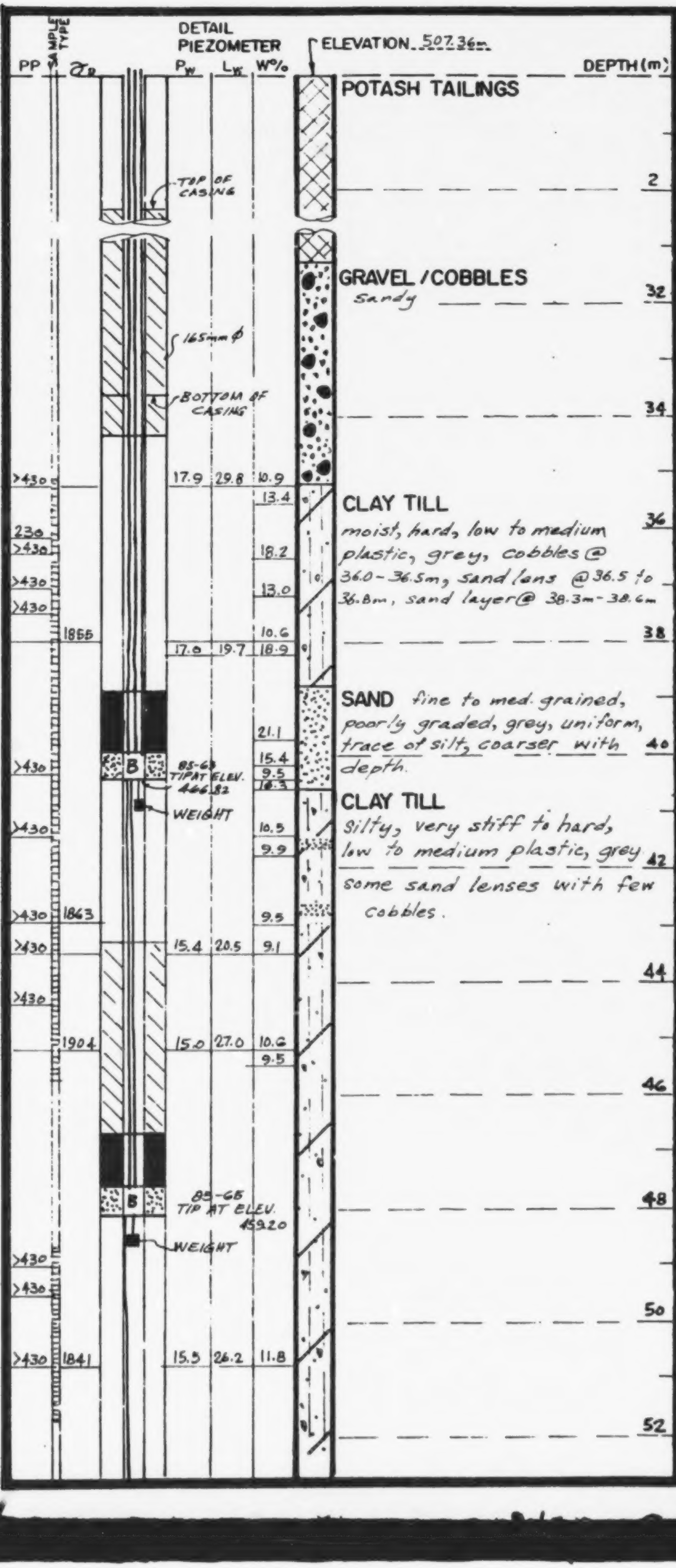
Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100

Date Drilled: JULY 30, 31, 1985
Date Installed: JULY 31, AND AUG. 9/85

DRAWING NUMBER: S85-1774-16


PP
SAMPLE TYPE
γ_D
DETAIL PIEZOMETER
P_W
L_W
W%
ELEVATION 507.36m
DEPTH (m)
TOP OF CASING
165mm φ
BOTTOM OF CASING
2
32
34
36
38
40
42
44
46
48
50
52
>430
17.9 29.8 10.9
13.4
230
>430
18.2
>430
13.0
>430
1855
10.6
17.0 19.7 18.9
21.1
15.4
>430
B
85-68 TIP AT ELEV. 466.82
9.5
18.3
WEIGHT
>430
10.5
9.9
>430 1863
9.5
>430
15.4 20.5 9.1
>430
1904
15.0 27.0 10.6
9.5
B
85-6B TIP AT ELEV. 459.20
WEIGHT
>430
>430
>430 1841
15.5 26.2 11.8

POTASH TAILINGS

GRAVEL / COBBLES
sandy

CLAY TILL
moist, hard, low to medium plastic, grey, cobbles @ 36.0 - 36.5m, sand lens @ 36.5 to 36.8m, sand layer @ 38.3m - 38.6m

SAND *fine to med. grained, poorly graded, grey, uniform, trace of silt, coarser with depth.*

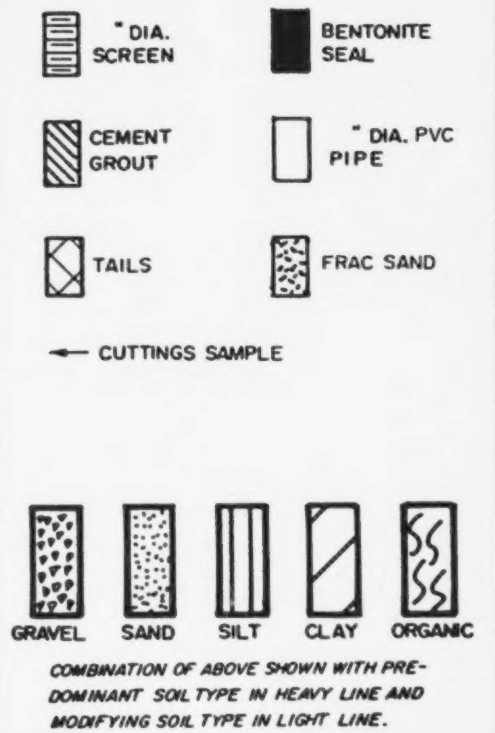
CLAY TILL
Silty, very stiff to hard, low to medium plastic, grey
some sand lenses with few cobbles.

TEST HOLE 85-68

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY MODEL 1250

LEGEND:


" DIA. SCREEN
BENTONITE SEAL
CEMENT GROUT
" DIA. PVC PIPE
TAILS
FRAC SAND
CUTTINGS SAMPLE
GRAVEL
SAND
SILT
CLAY
ORGANIC

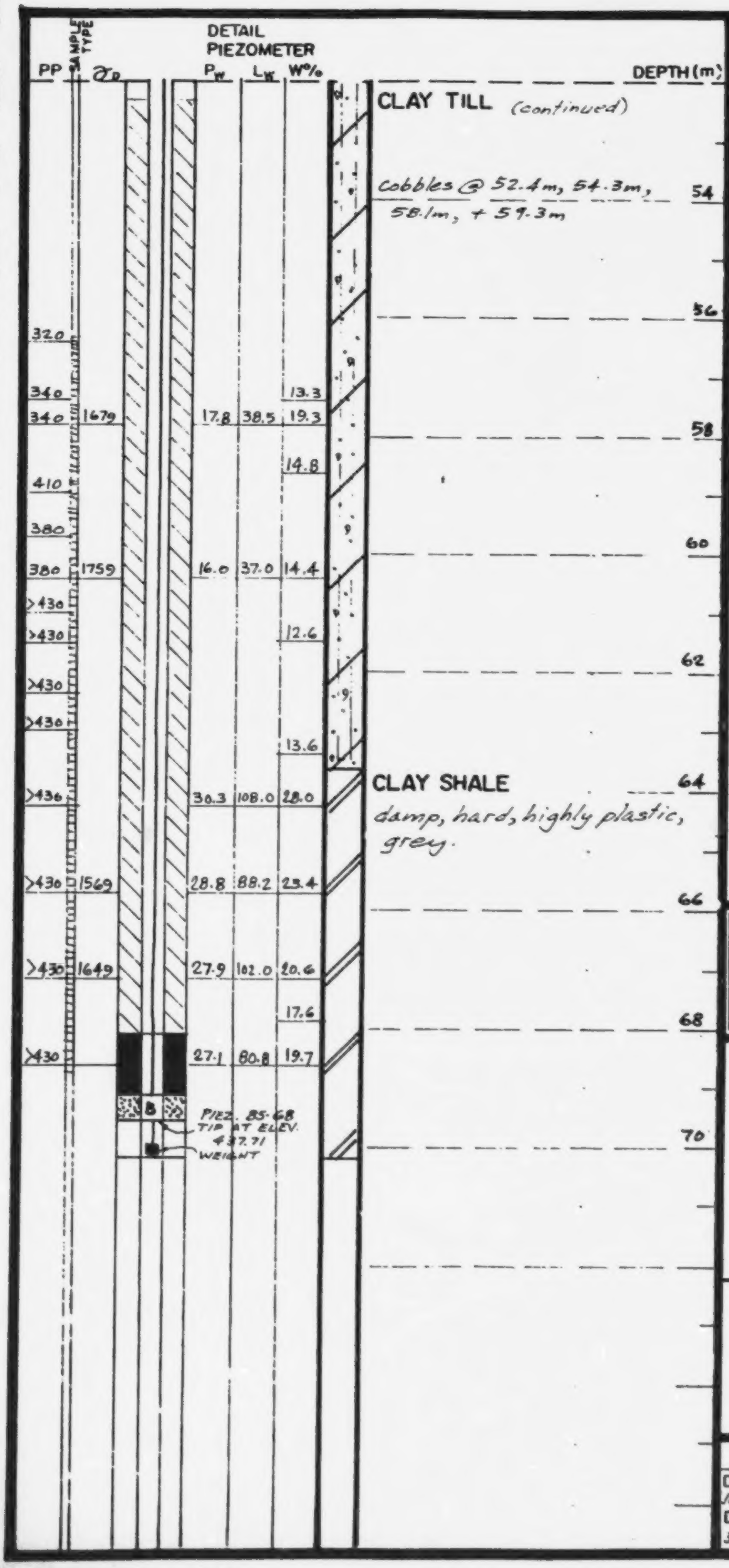
COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100 Date Drilled: MAY 8, JULY 26, JULY 27, 28/85 Date Installed: JULY 29, 31, and AUG. 2/85	DRAWING NUMBER : S85-1774-17


PP
SAMPLE TYPE
γ_D
DETAIL PIEZOMETER
P_W
L_W
W%
DEPTH (m)
54
56
58
60
62
64
66
68
70
B
PIEZ. 85-68 TIP AT ELEV. 437.71
WEIGHT

PP	γ_D	P_W	L_W	W%
320				
340				13.3
340	1679	17.8	38.5	19.3
				14.8
410				
380				
380	1759	16.0	37.0	14.4
>430				
>430				12.6
>430				
>430				
				13.6
>430		30.3	108.0	28.0
>430	1569	28.8	88.2	23.4
>430	1649	27.9	102.0	20.6
				17.6
>430		27.1	80.8	19.7

CLAY TILL *(continued)*

cobbles @ 52.4m, 54.3m, 58.1m, + 59.3m

CLAY SHALE

damp, hard, highly plastic, grey.

TEST HOLE 85-68

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS TEST HOLE AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME.

DRILL RIG: FAILING ROTARY
MODEL 1250

LEGEND:

☰ " DIA. SCREEN	■ BENTONITE SEAL
▨ CEMENT GROUT	☐ " DIA. PVC PIPE
☒ TAILS	▩ FRAC SAND

← CUTTINGS SAMPLE

GRAVEL	SAND	SILT	CLAY	ORGANIC

COMBINATION OF ABOVE SHOWN WITH PREDOMINANT SOIL TYPE IN HEAVY LINE AND MODIFYING SOIL TYPE IN LIGHT LINE.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

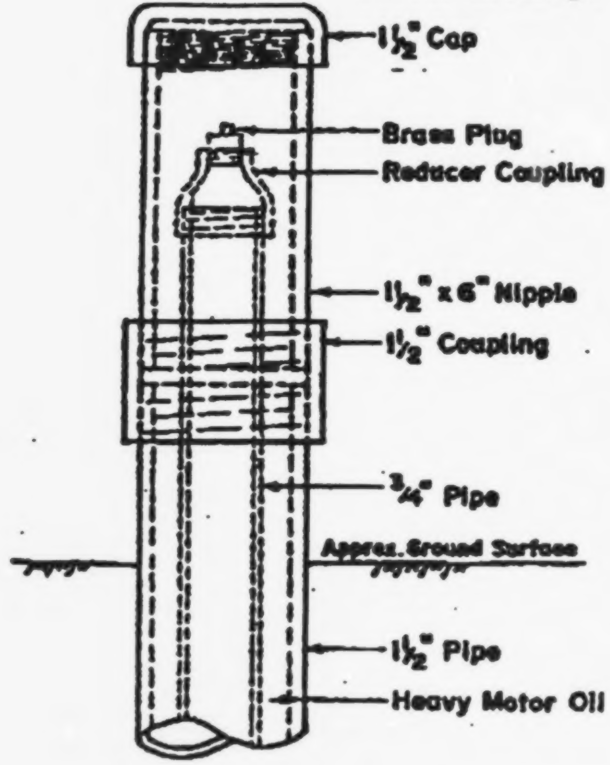
TEST HOLE LOG AND PIEZOMETER DETAIL

SCALE 1:100

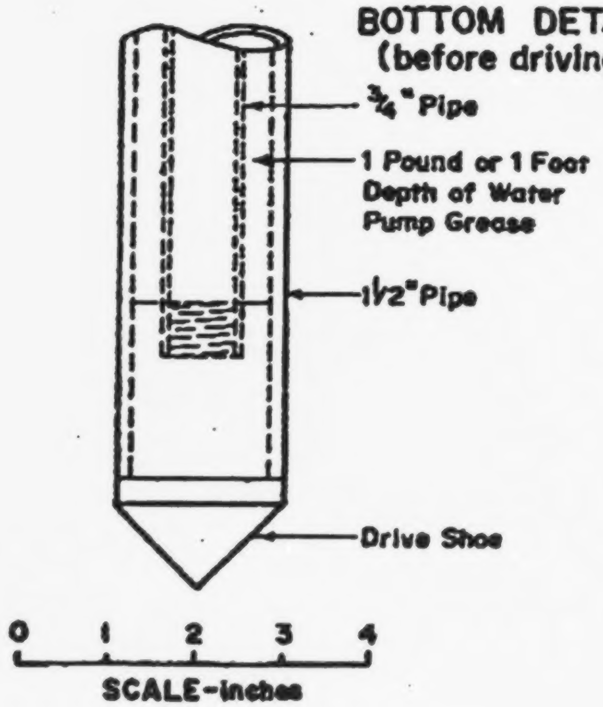
Date Drilled: MAY 8, JULY 26, 27, 28, /85
Date Installed: JULY 29, 31, and AUG. 2/85.

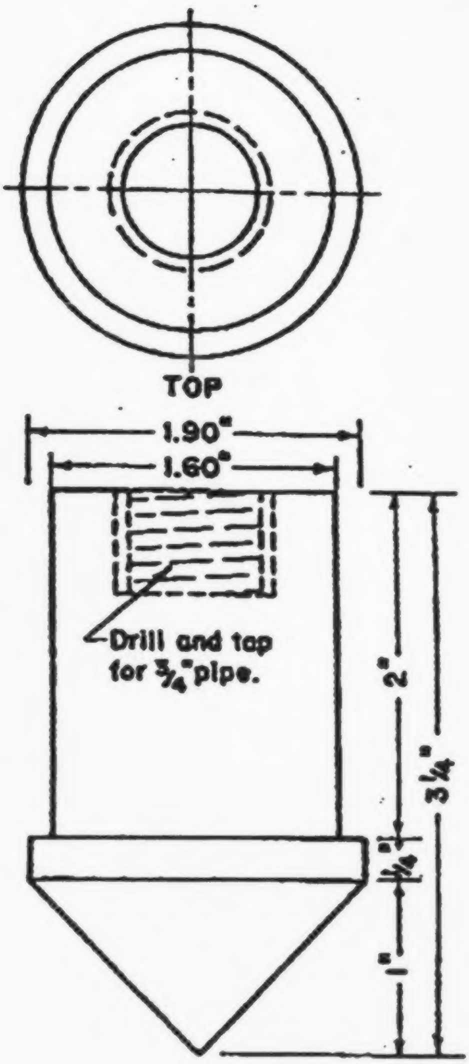
DRAWING NUMBER:
S85-1774-18

TOP DETAIL
(after driving)

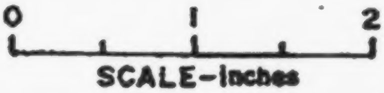

1½" Cap
Brass Plug
Reducer Coupling
1½" x 6" Nipple
1½" Coupling
¾" Pipe
Approx. Ground Surface
1½" Pipe
Heavy Motor Oil

BOTTOM DETAIL
(before driving)


¾" Pipe
1 Pound or 1 Foot
Depth of Water
Pump Grease
1½" Pipe
Drive Shoe
0
1
2
3
4
SCALE-inches


TOP
1.90"
1.60"
Drill and tap
for ¾" pipe.
2"
¼"
1"
3¼"

DRIVE SHOE


0
1
2
SCALE-inches

Note: Special drive shoe made up at machine shop.

B - Revised - January 31, 1980.
A - Revised - January 5, 1979.

DEEP BENCH MARK ASSEMBLY

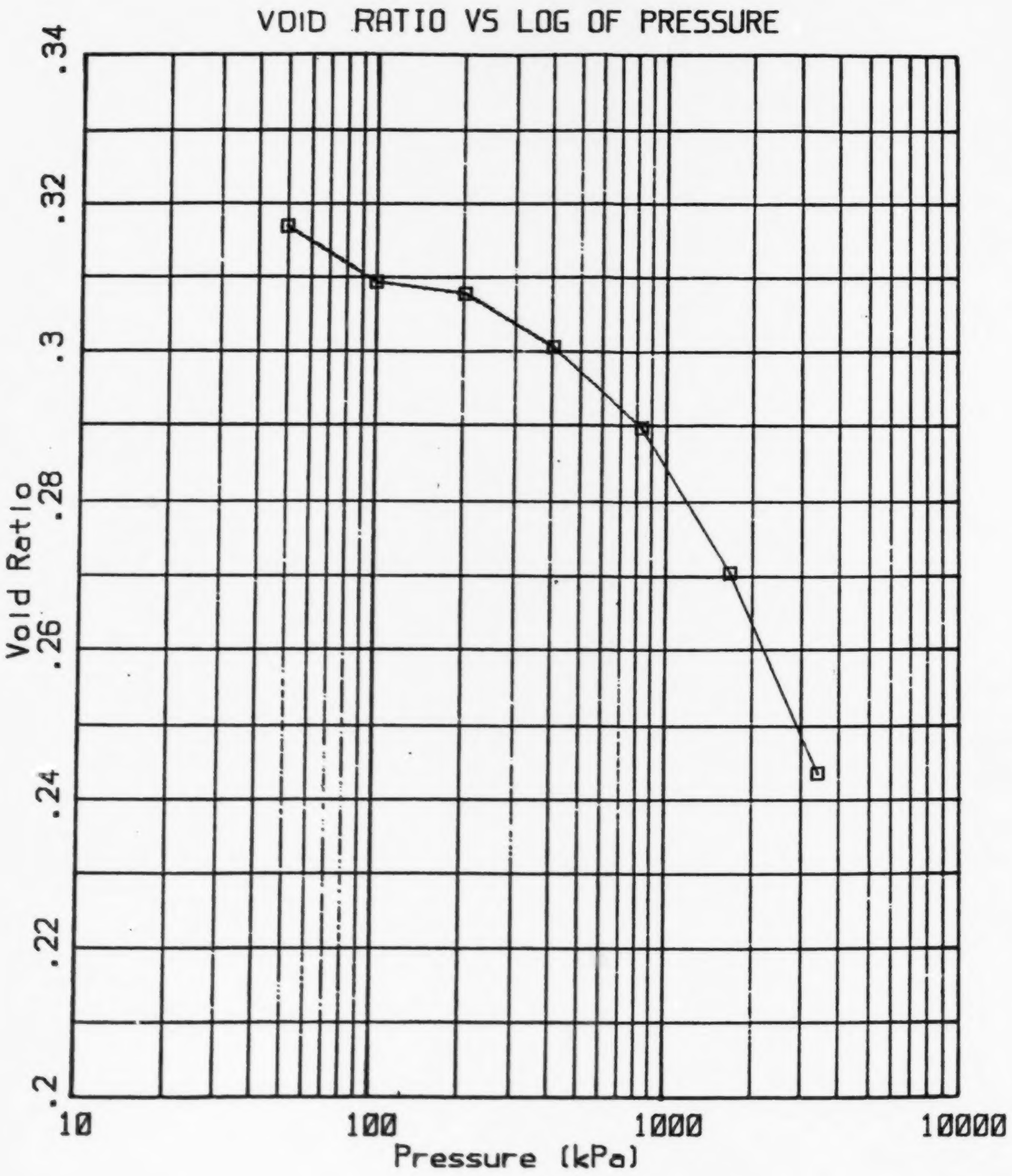
APPENDIX 3

Consolidation Test Results

APPENDIX 3

Consolidation Test Results

Test Hole No.	Depth (m)
85-53	20.3 - 20.4
85-53	22.1 - 22.2
85-53	31.1 - 31.2
85-58	38.6 - 38.7
85-58	41.0
85-58	41.9 - 42.0
85-58	43.7 - 43.9
85-68	43.0
85-68	50.6 - 50.7
85-68	57.9
85-68	68.4



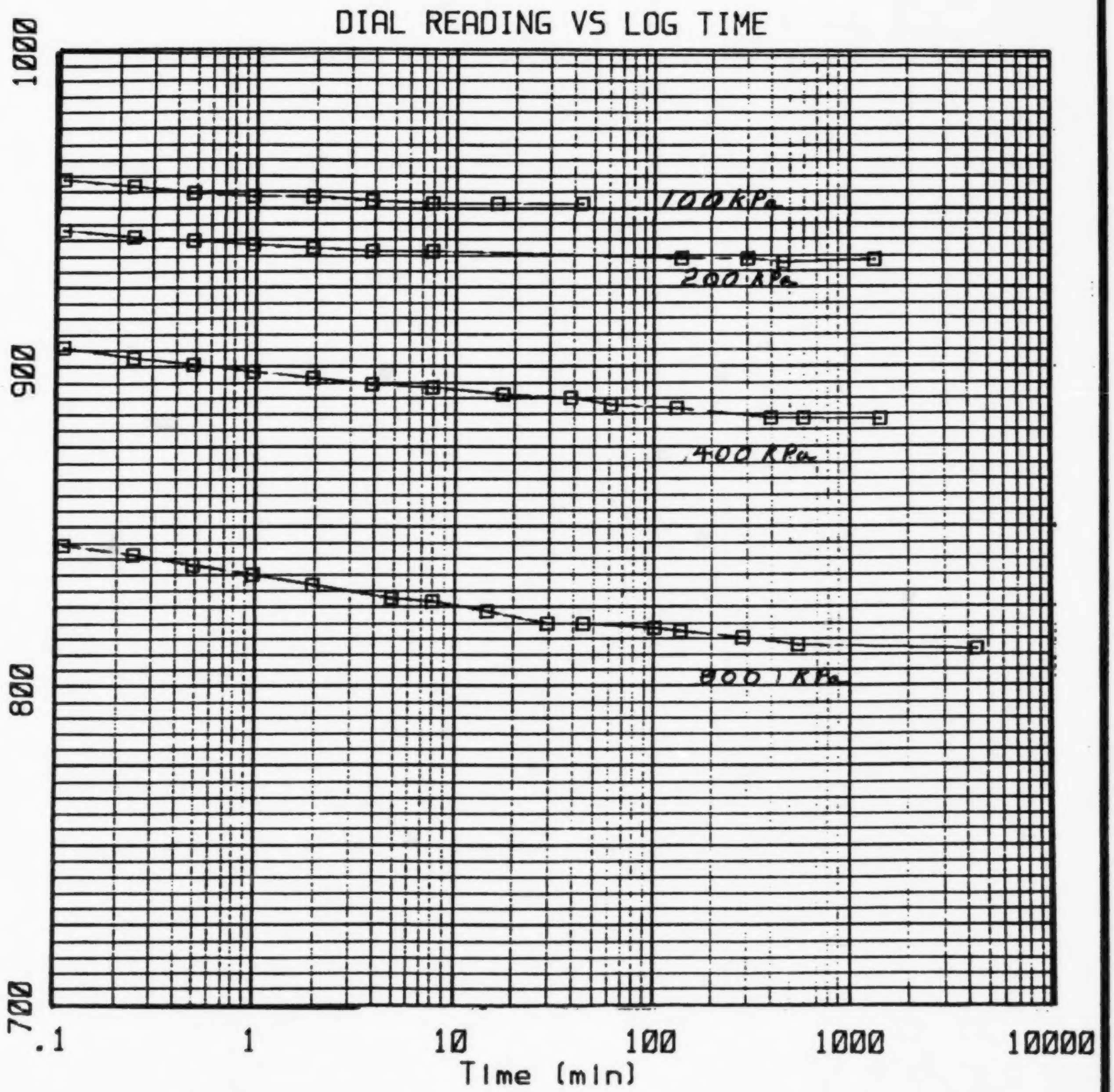
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

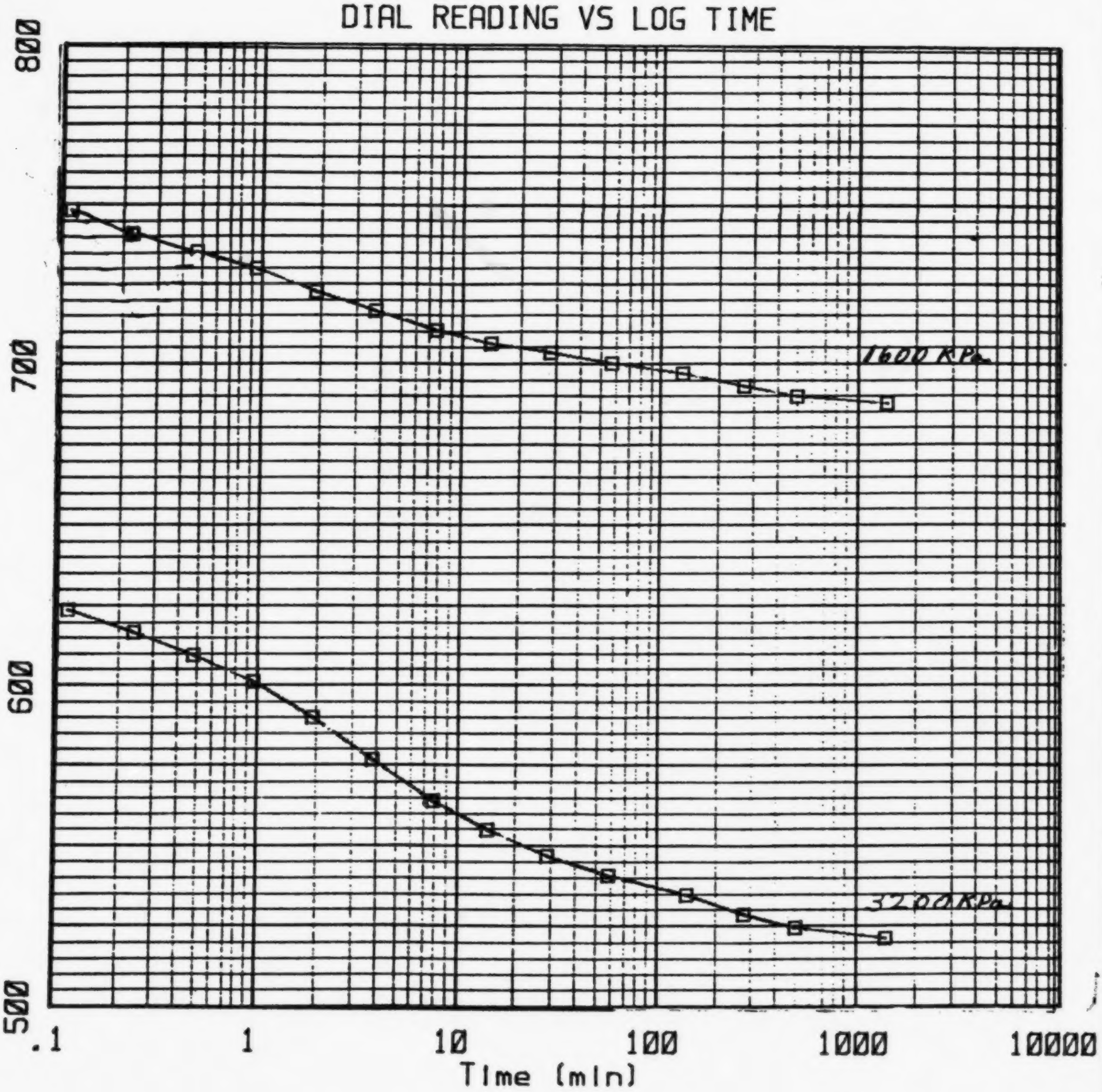
CONSOLIDATION TEST

TEST HOLE NO: 85-53 DEPTH: 20 m

PROJECT NO: S85-1774



BBT Geotechnical Consultants Ltd. BBT GEOTECHNICAL CONSULTANTS LTD.	**Tails Pile Instrumentation** PCS ROCANVILLE
CONSOLIDATION TEST	TEST HOLE NO: 86-69 DEPTH: 2.0 m. PROJECT NO: S85-1774


DIAL READING VS LOG TIME

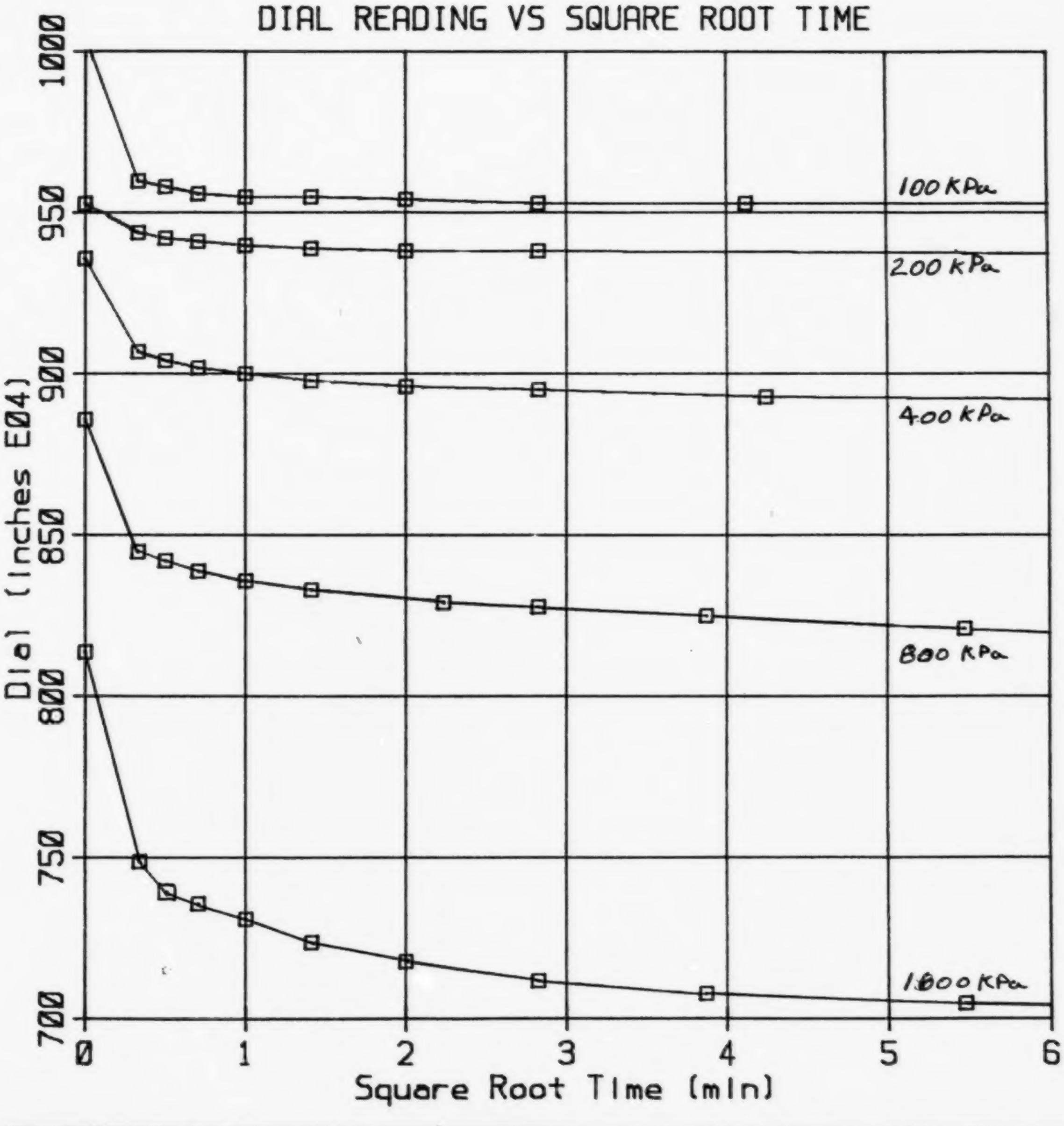
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 85-53 DEPTH: 20m

PROJECT NO: S85-1774



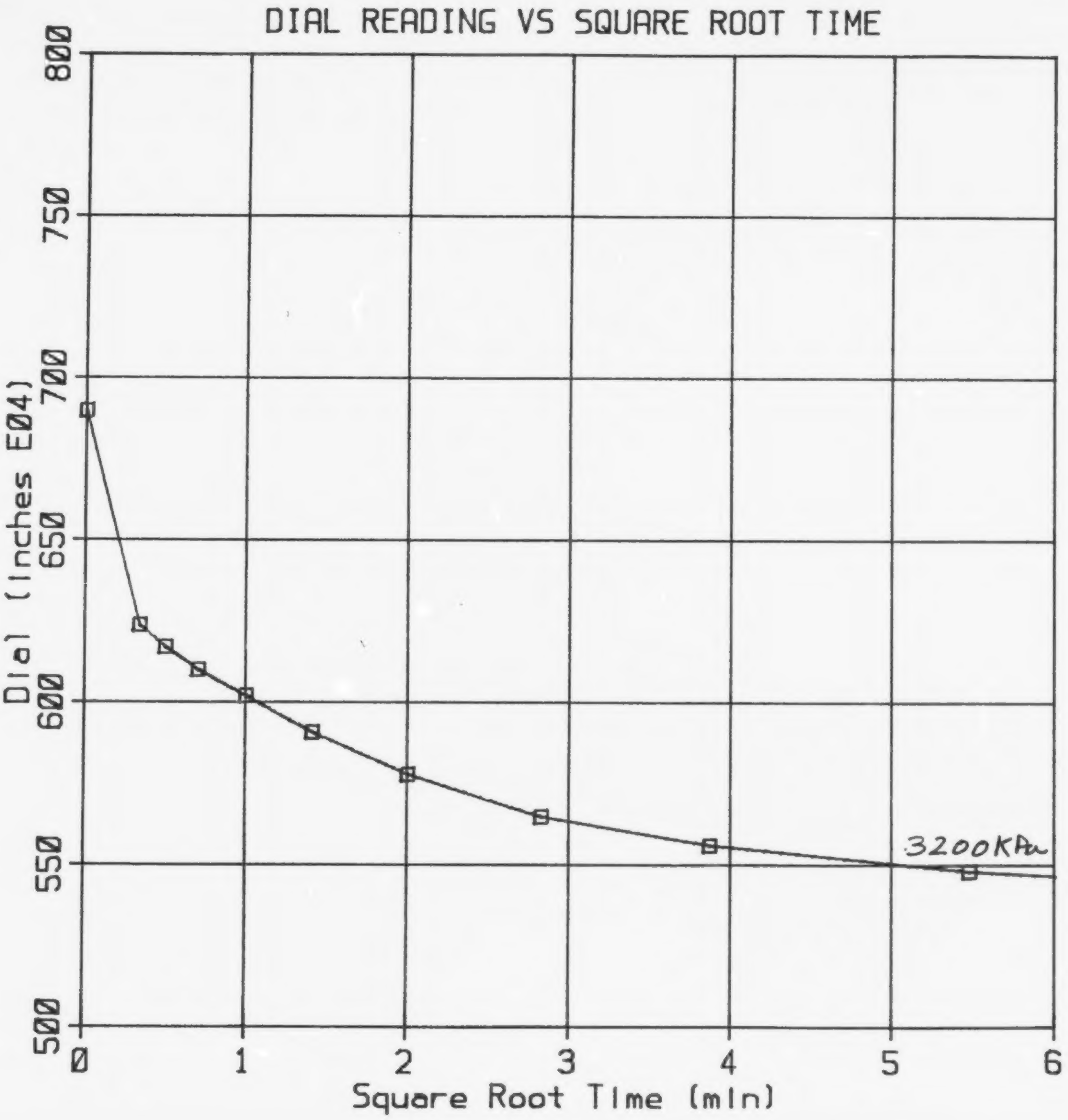
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 85-53 DEPTH: 20 m

PROJECT NO: S85-1774



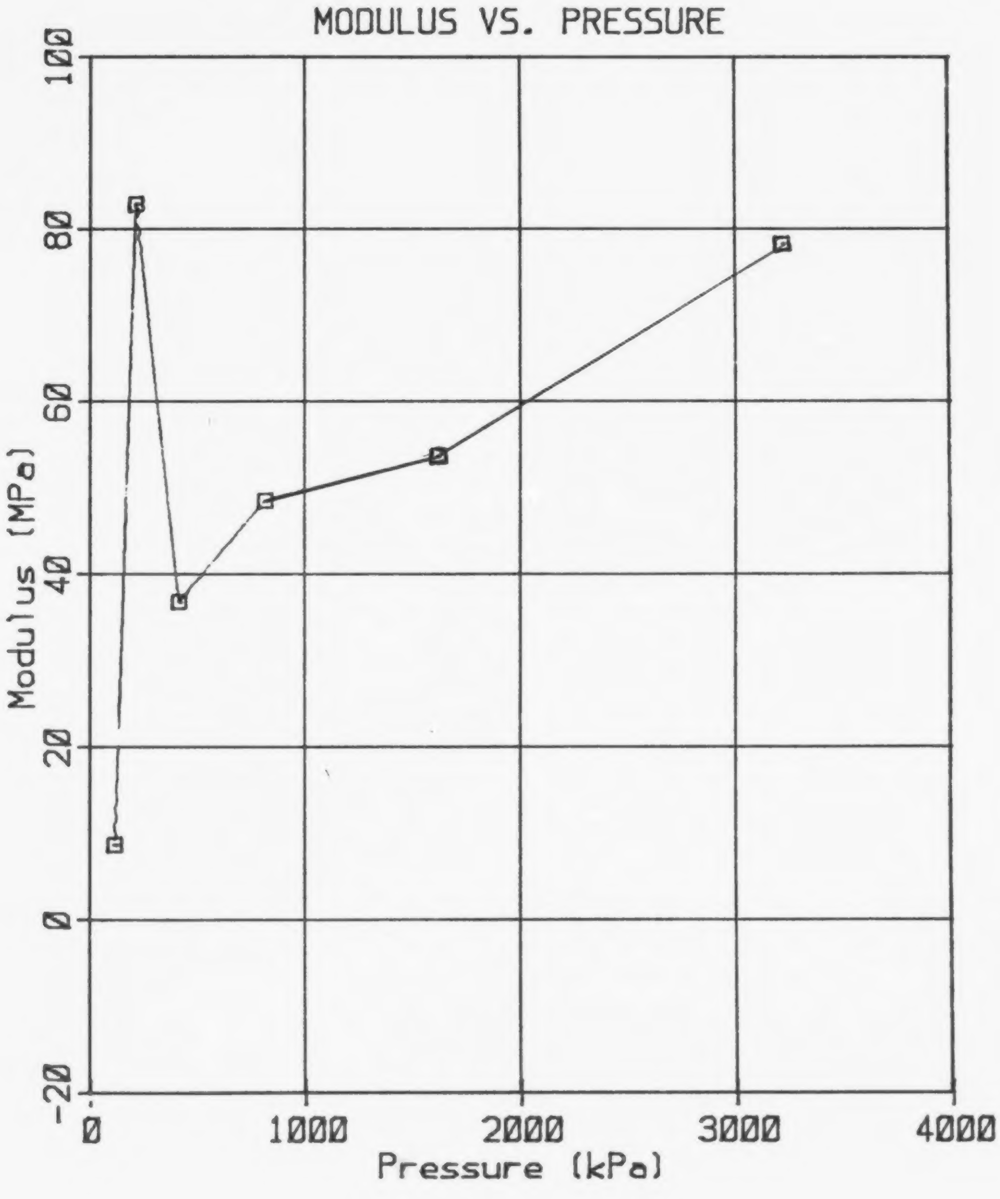
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 86-53 DEPTH: 20m

PROJECT NO: S85-1774



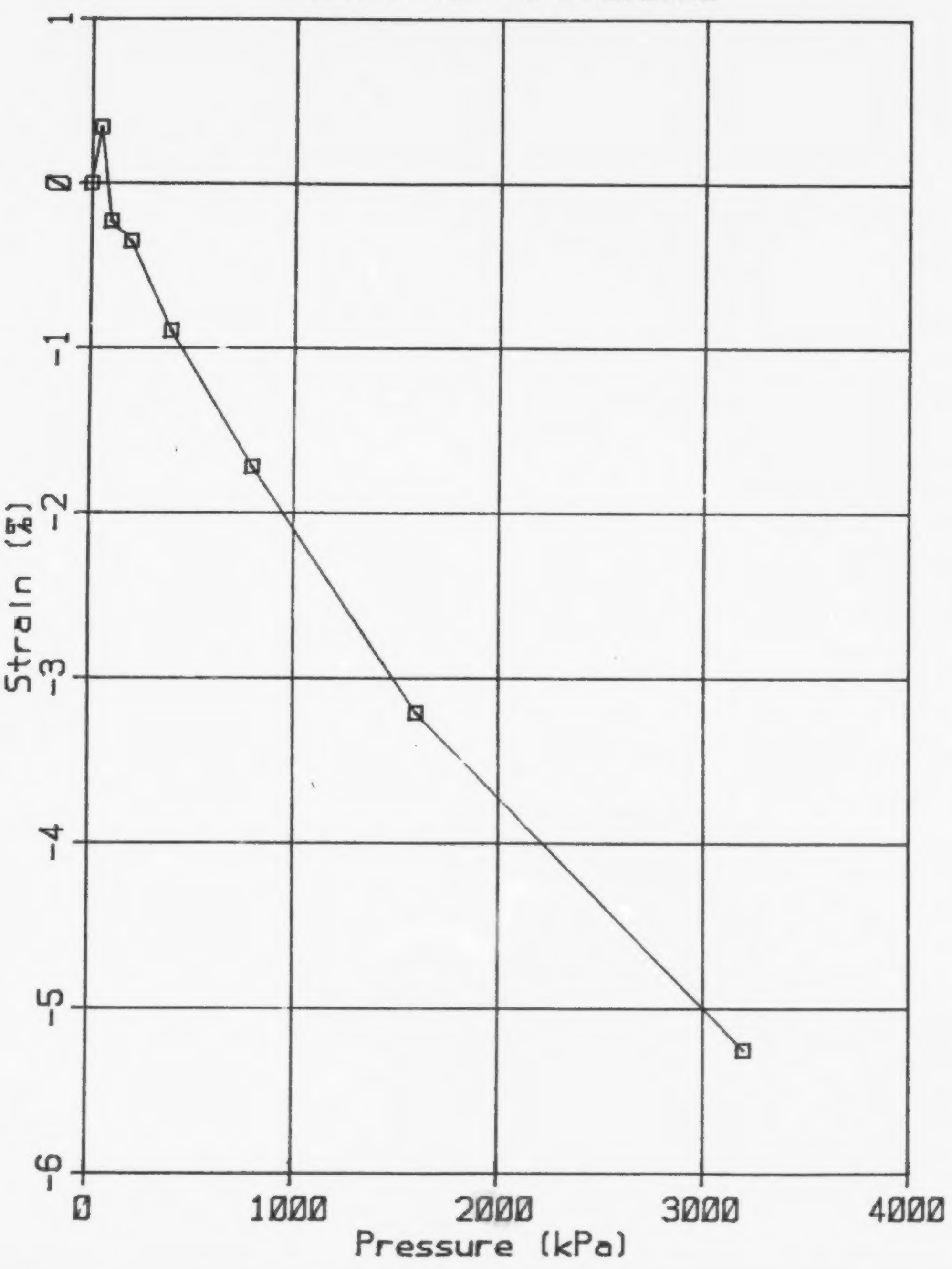
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 85-55 DEPTH: 20 m

PROJECT NO: S85-1774



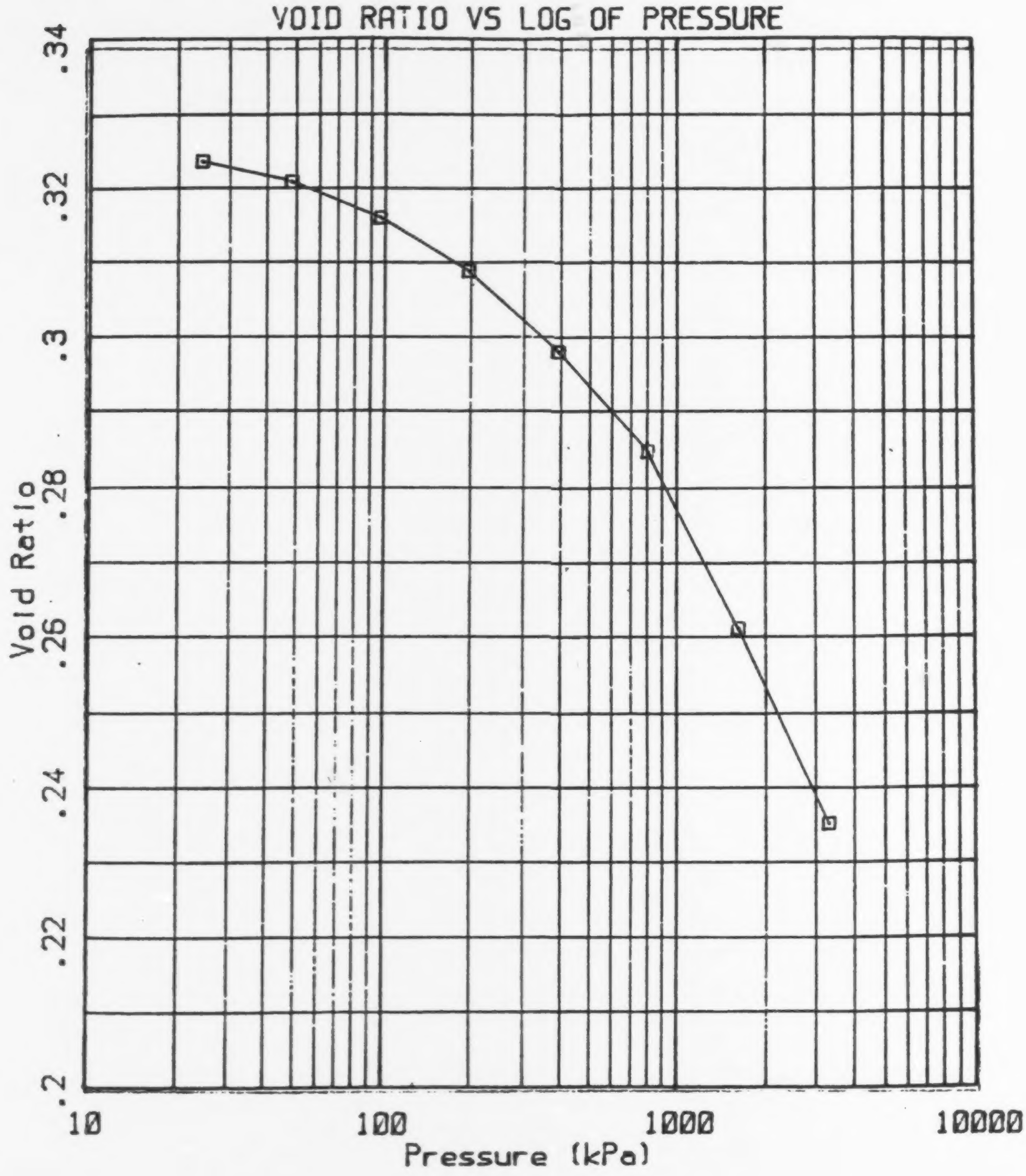
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 85-53 DEPTH: 20 m

PROJECT NO: S85-1774



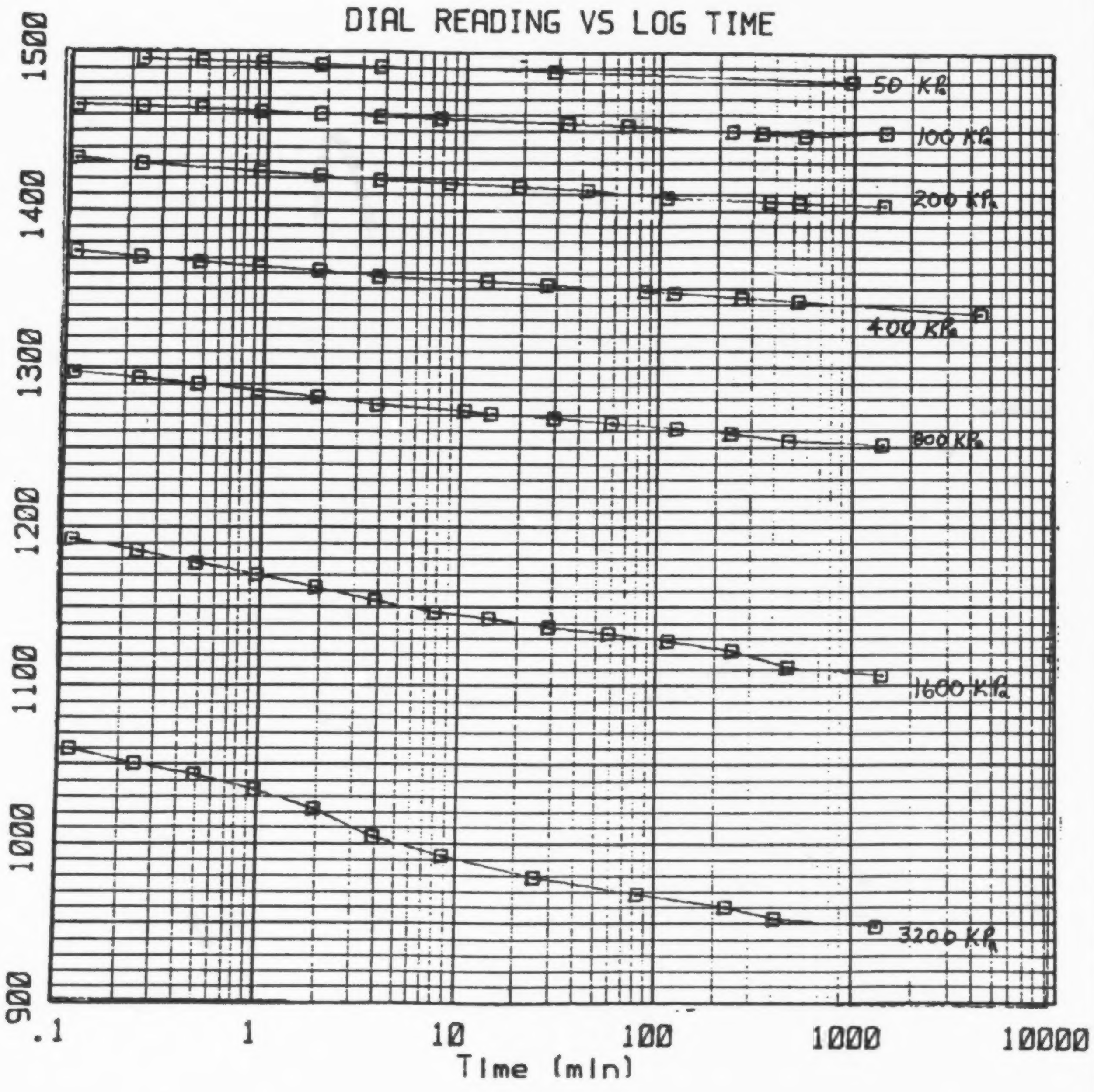
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 22.1–22.2 m

PROJECT NO: S85-1774



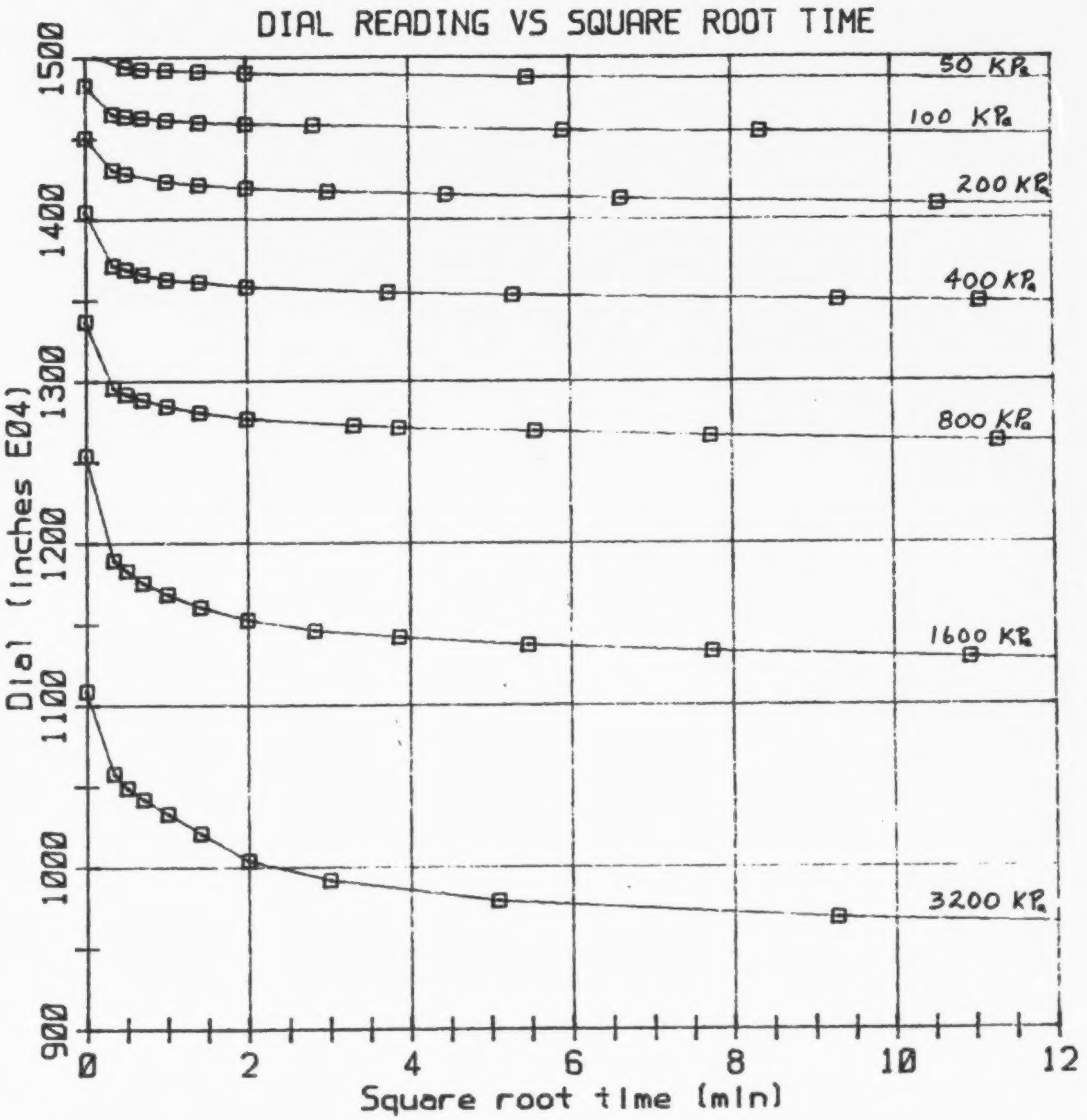
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 22.1-22.2

PROJECT NO: S85-1774



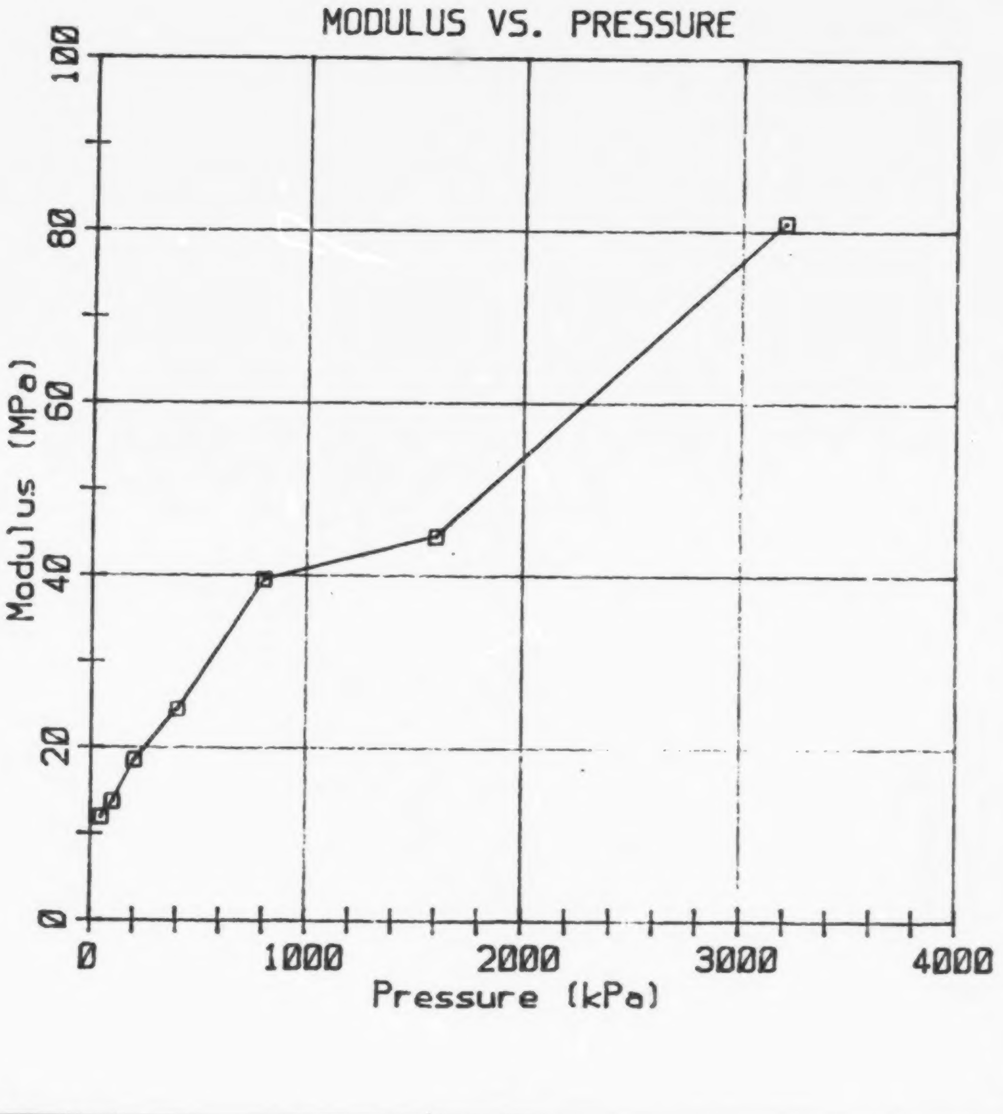
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 22.1-22.2 m

PROJECT NO: S85-1774



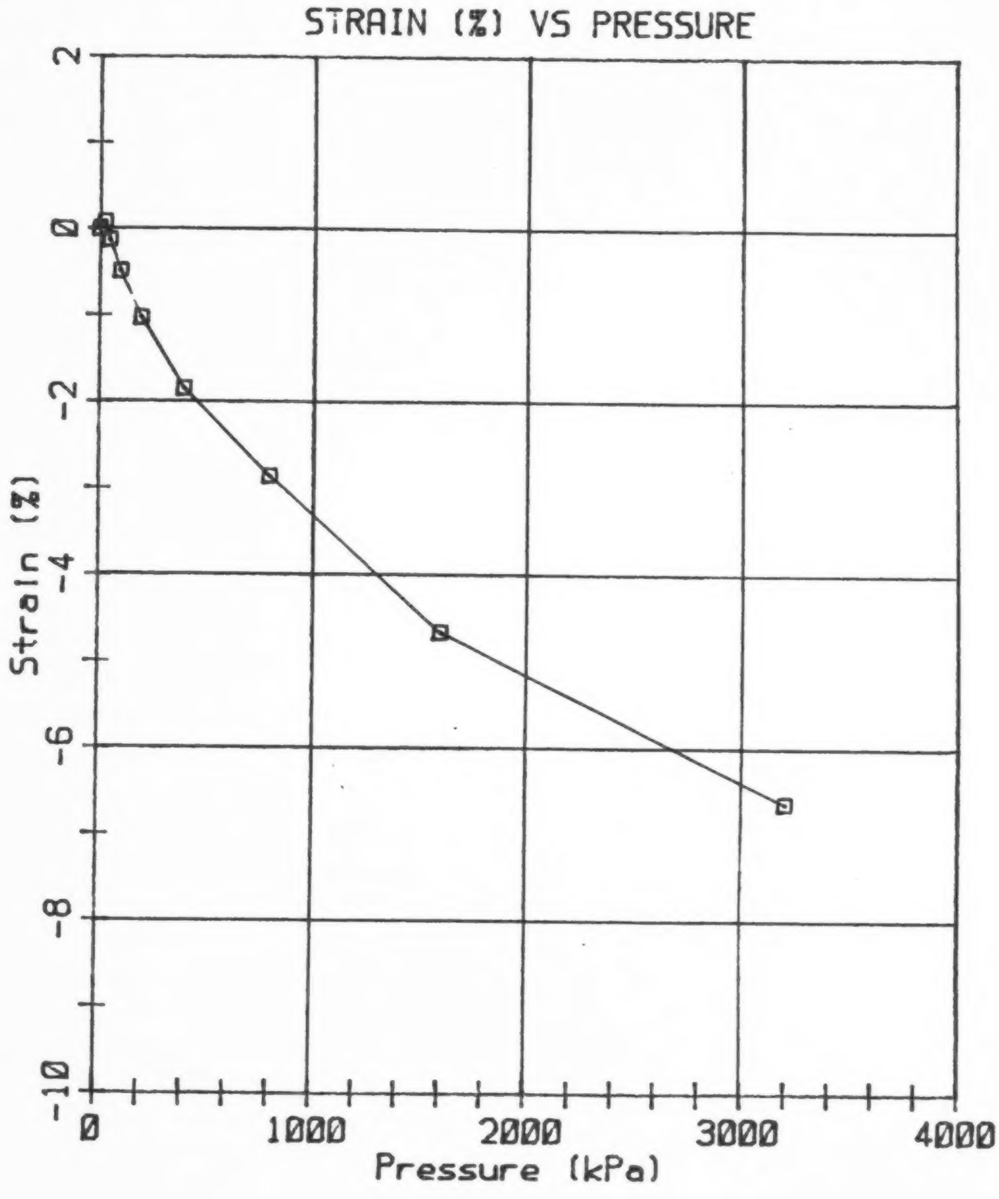
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 22.1–22.2m

PROJECT NO: S85-1774



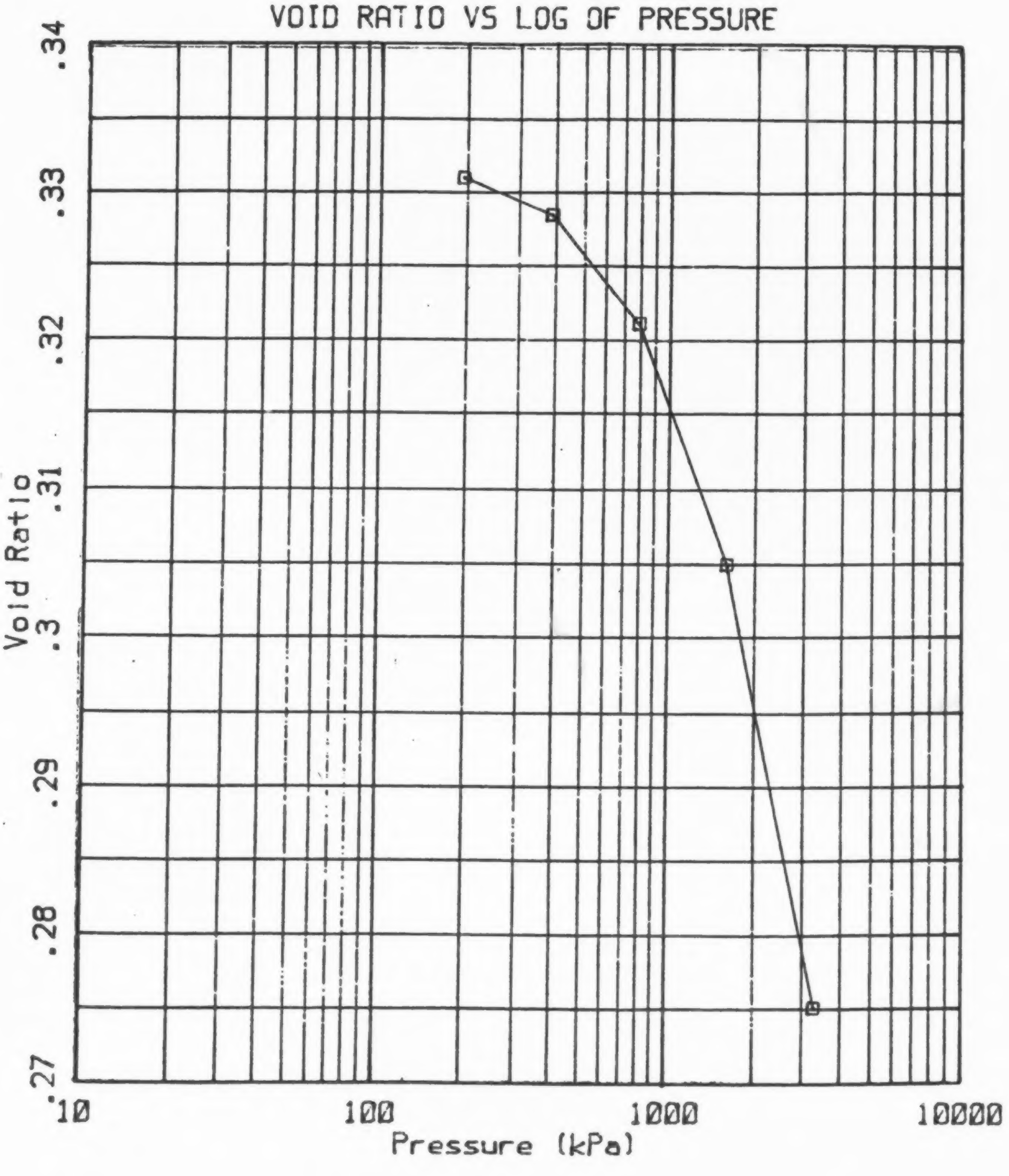
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 22.1-22.2m

PROJECT NO: S85-1774



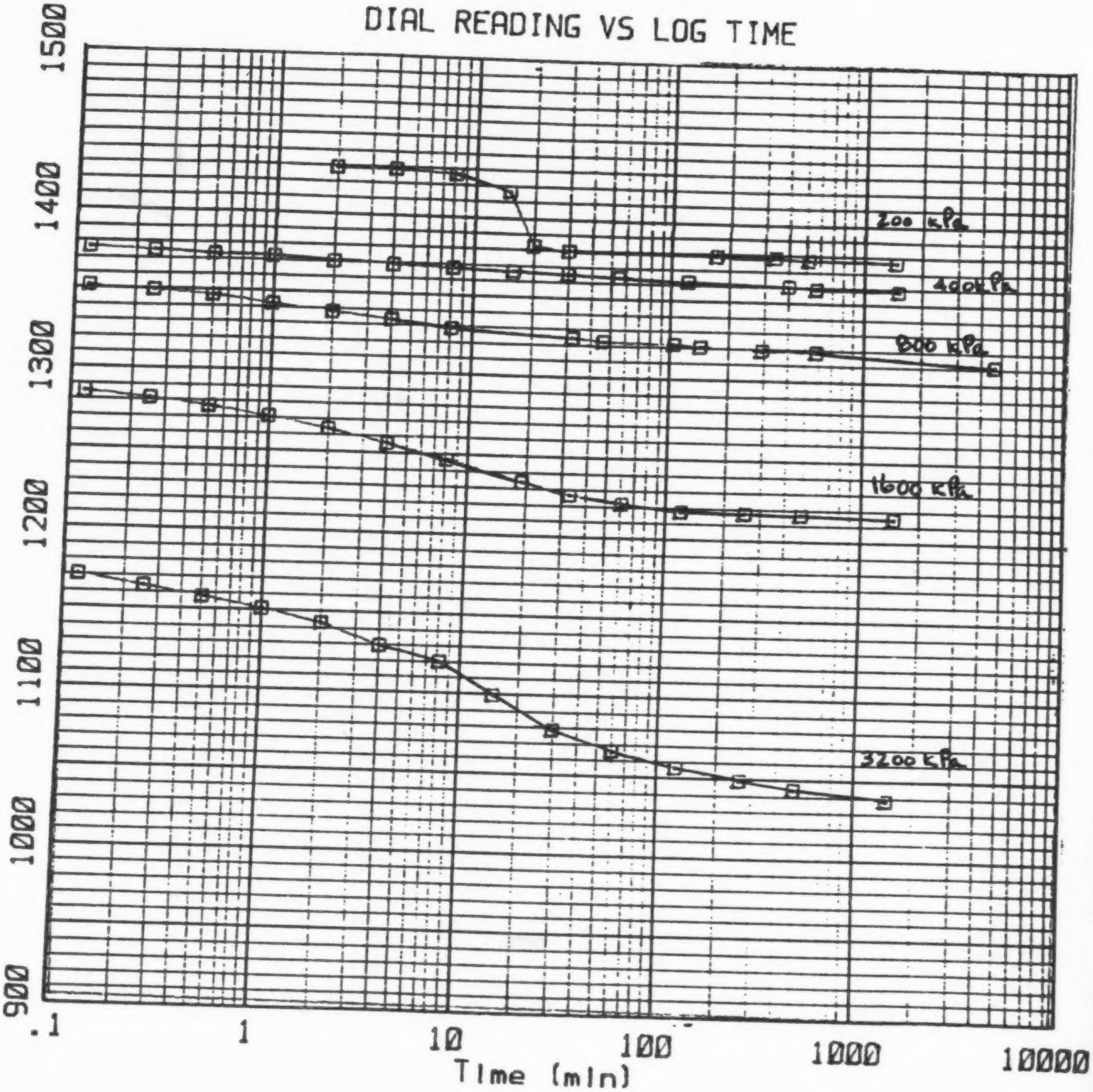
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 31.1 - 31.2m

PROJECT NO:
S85-1774



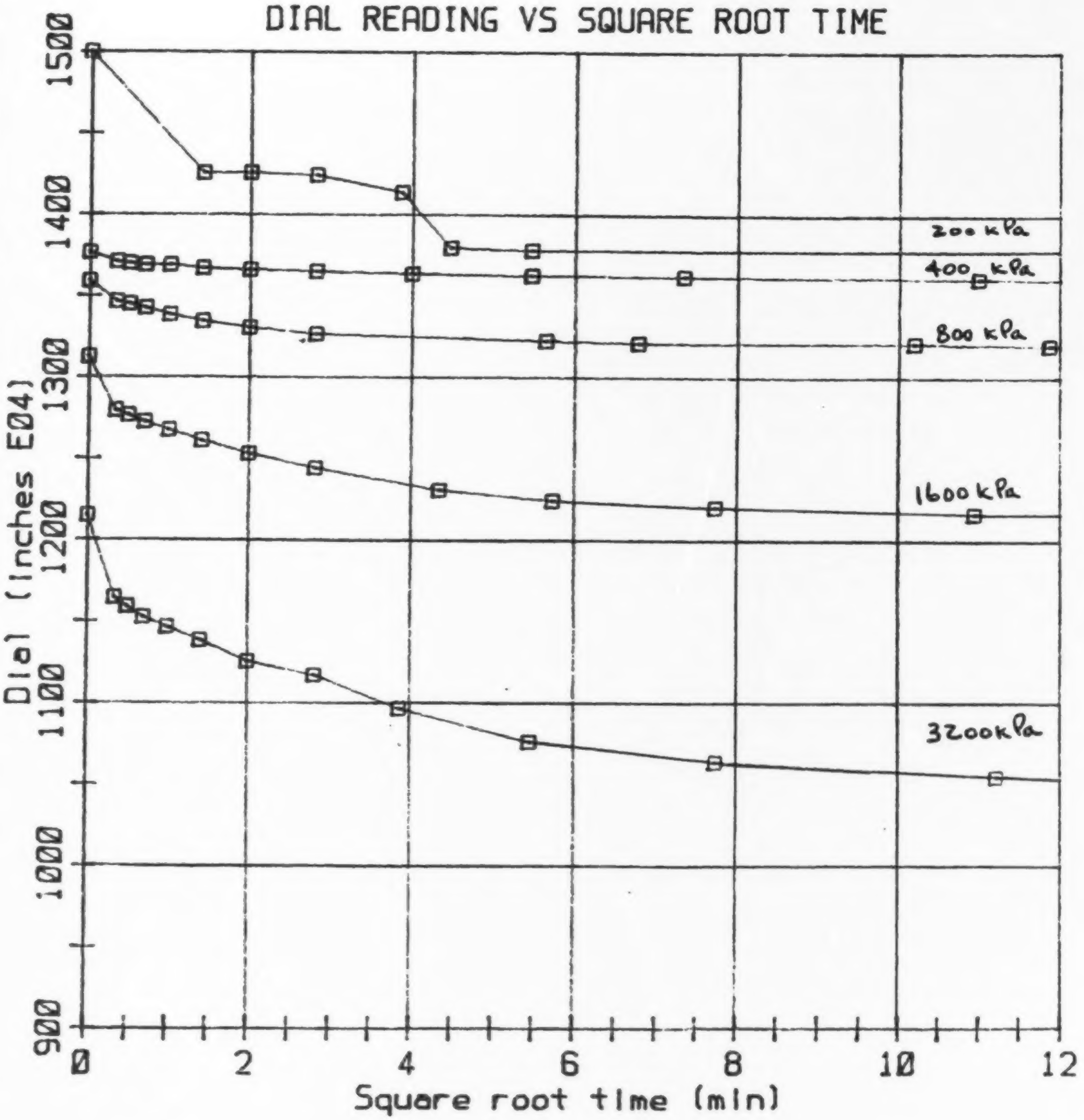
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 31.1– 31.2 m

PROJECT NO: S85-1774



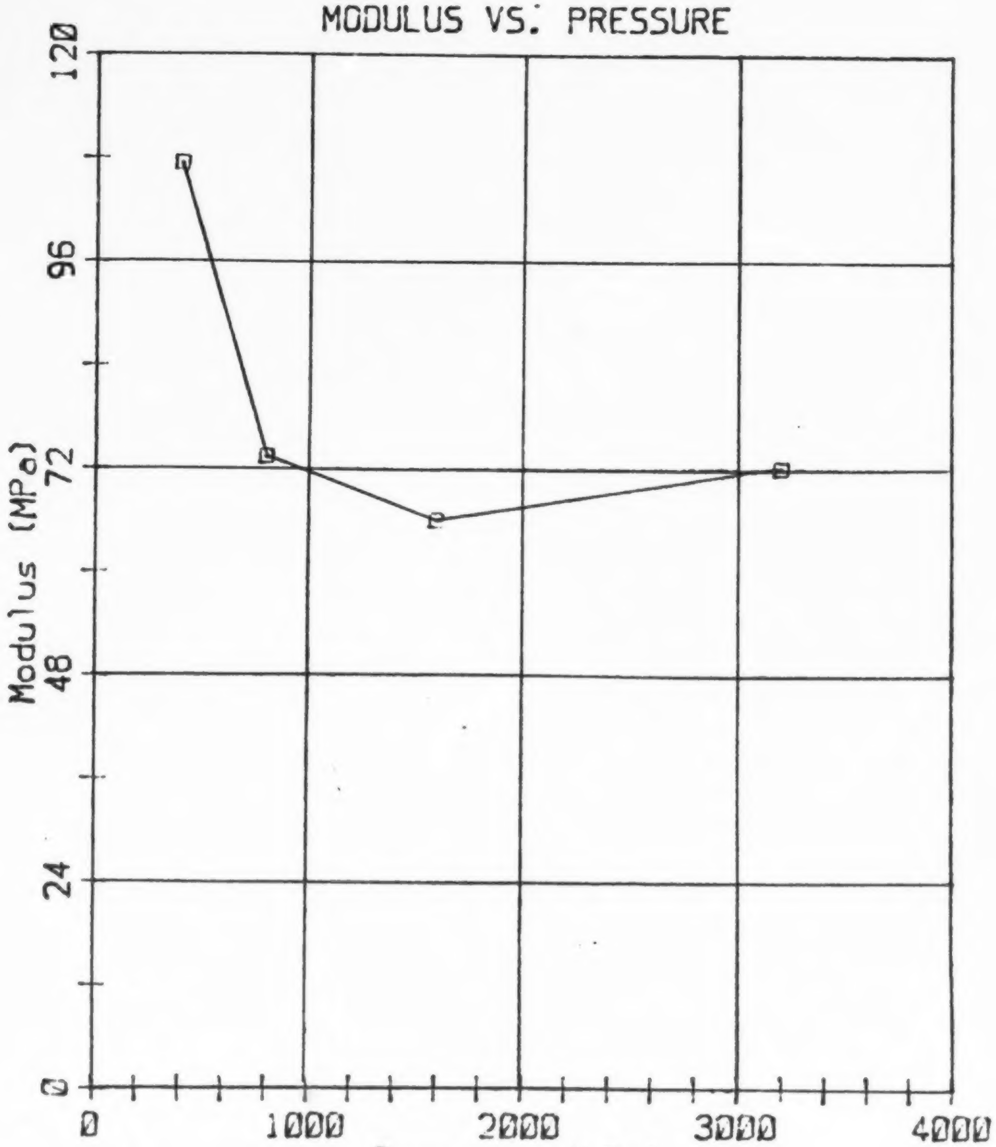
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 31.1 – 31.2m

PROJECT NO: S85-1774



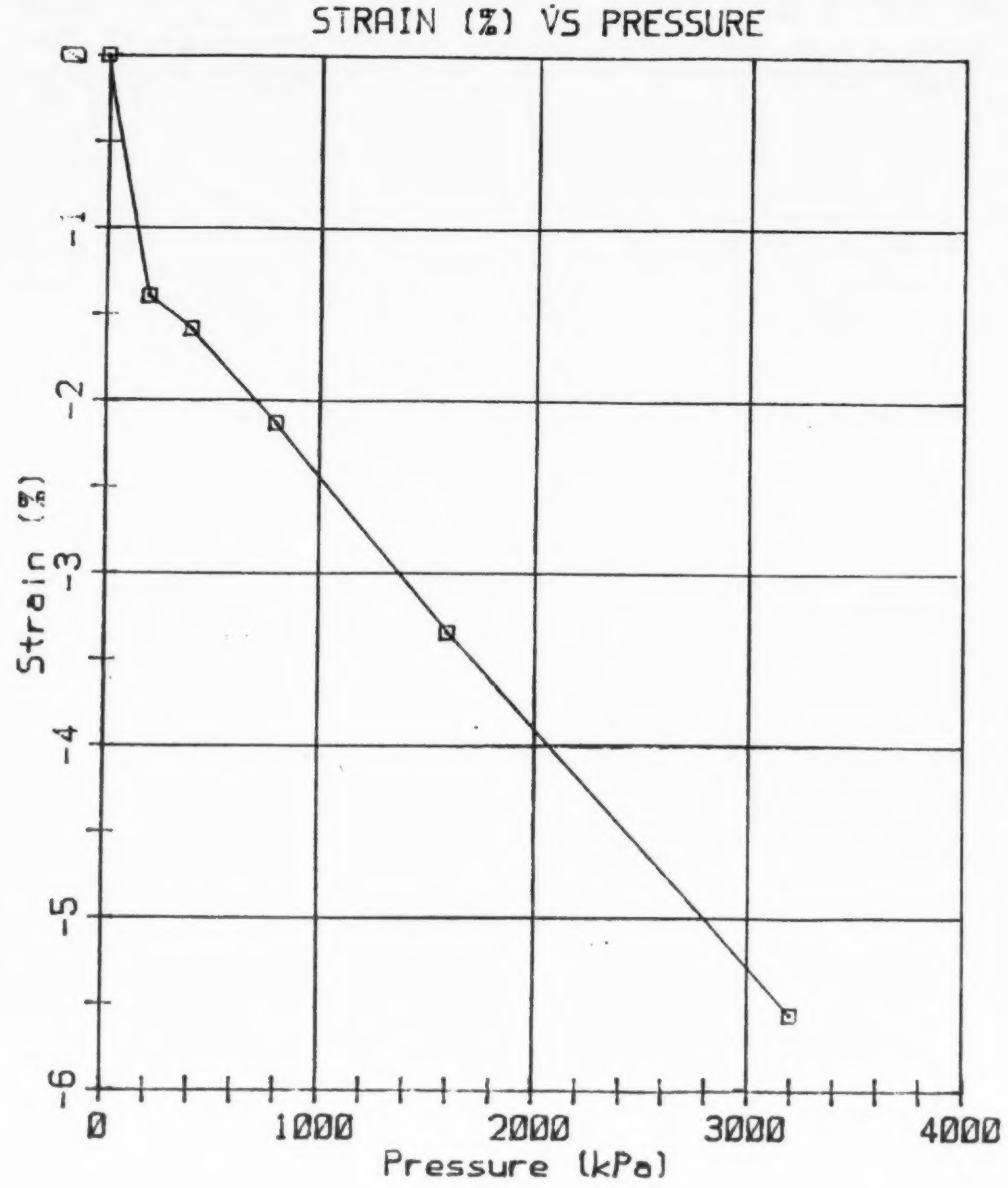
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 31.1–31.2m

PROJECT NO: S85-1774



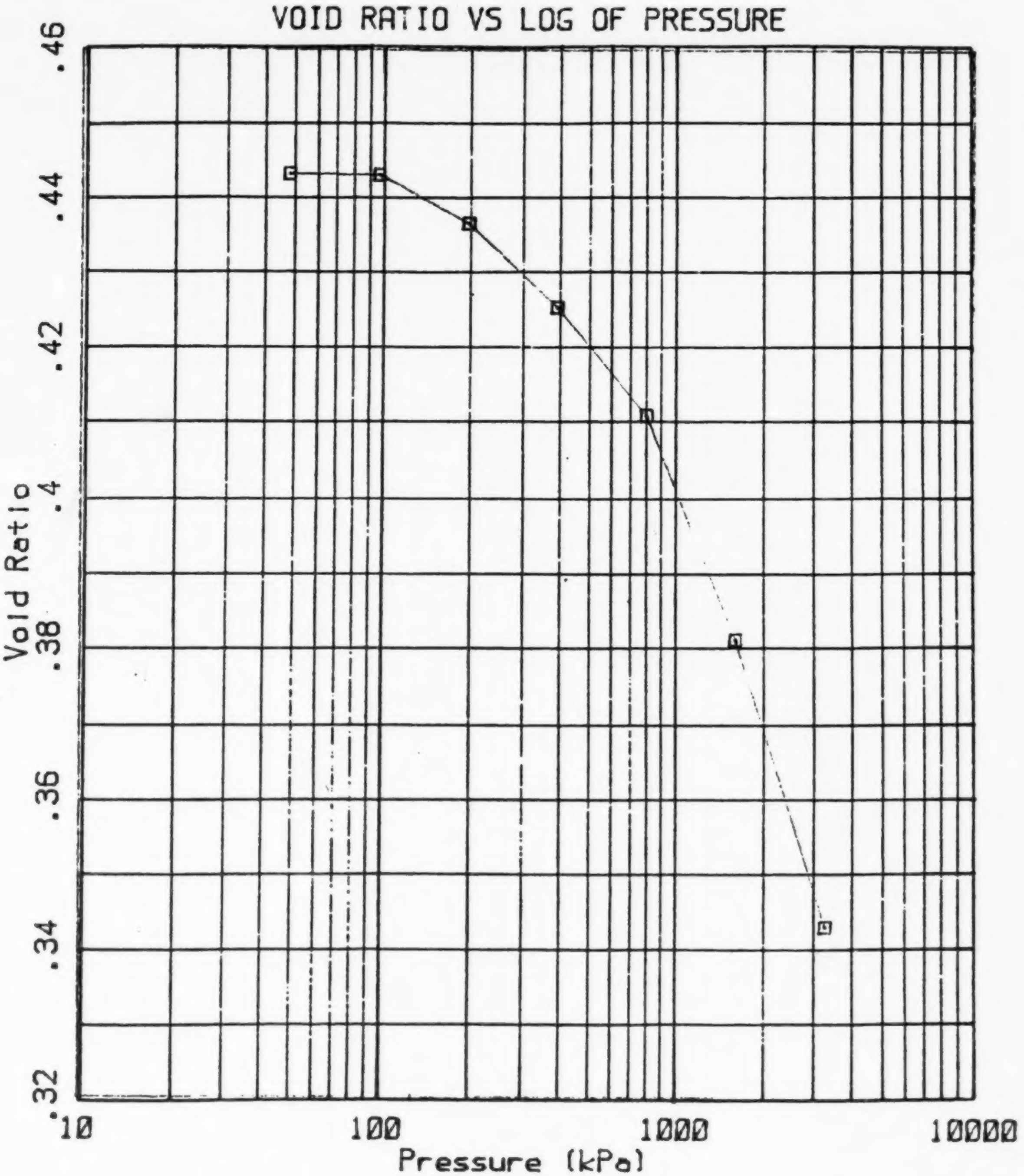
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

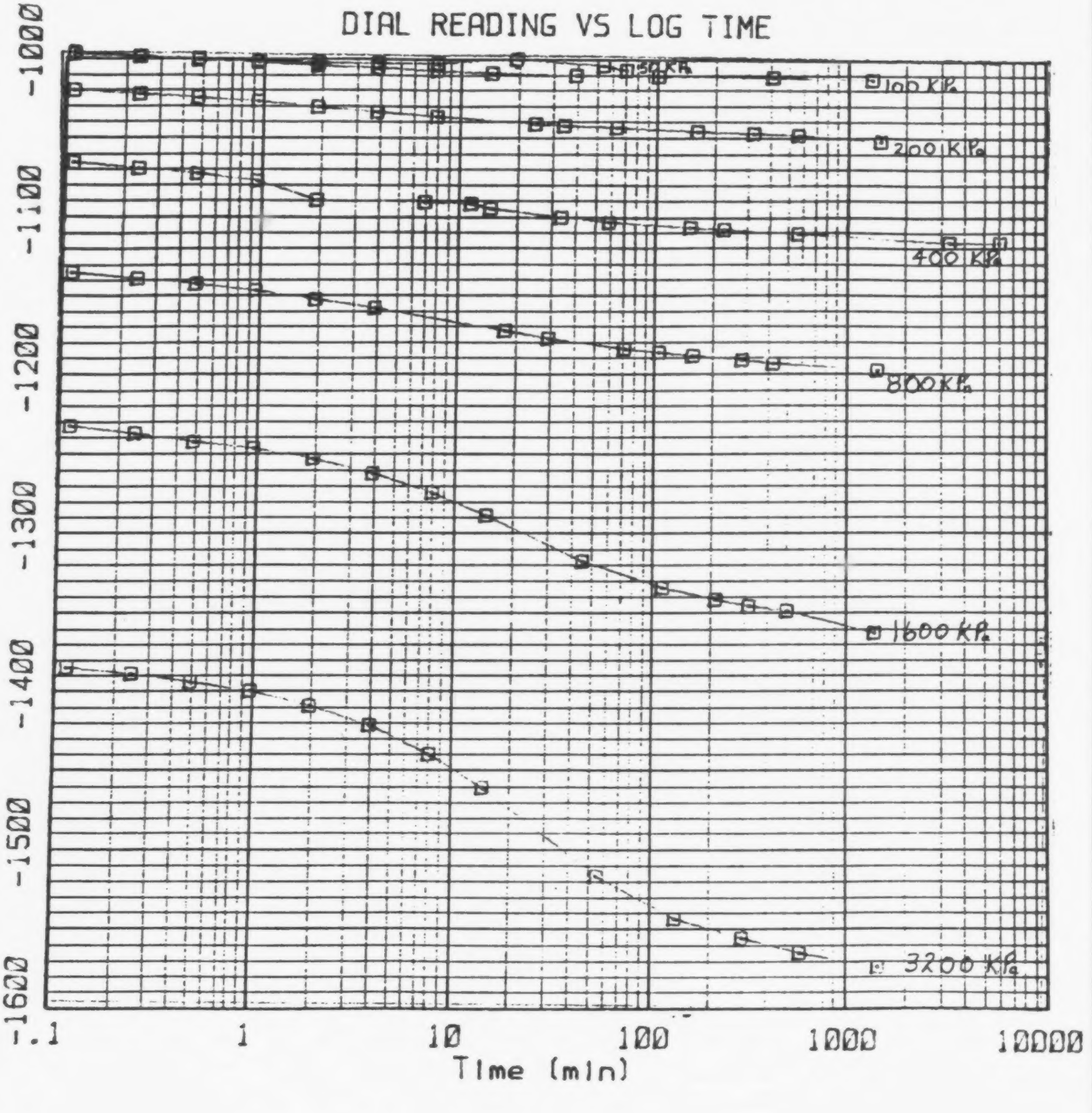
CONSOLIDATION TEST

TEST HOLE NO: 53 DEPTH: 31.1–31.2m

PROJECT NO: S85-1774



BBT Geotechnical Consultants Ltd. BBT GEOTECHNICAL CONSULTANTS LTD.	**Tails Pile Instrumentation** PCS ROCANVILLE
CONSOLIDATION TEST	TEST HOLE NO: 58 DEPTH: 38.6 – 38.7m · PROJECT NO: S85-1774



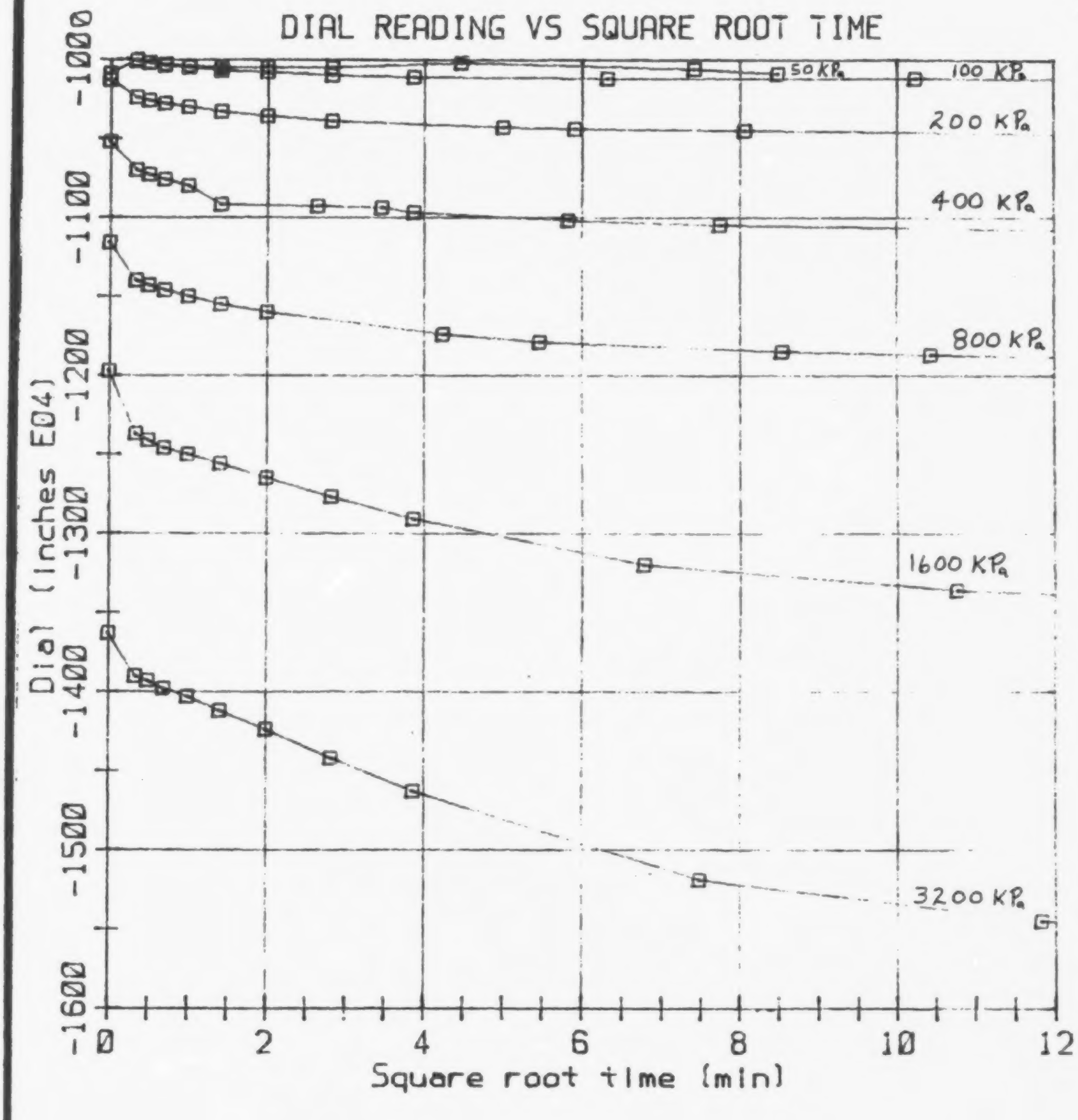
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 38.6-38.7

PROJECT NO: S85-1774



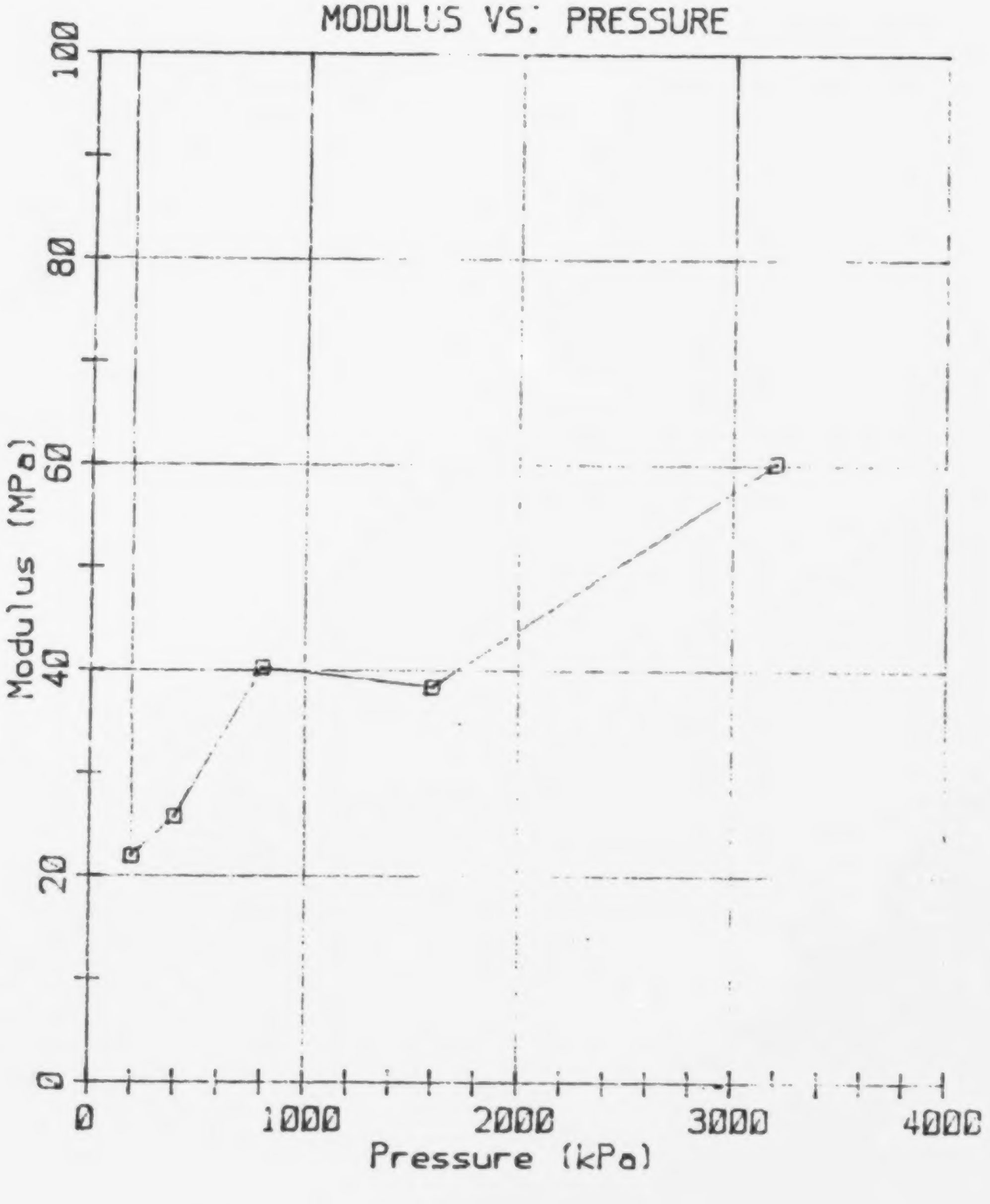
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 38.6-38.7

PROJECT NO: S85-1774



BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

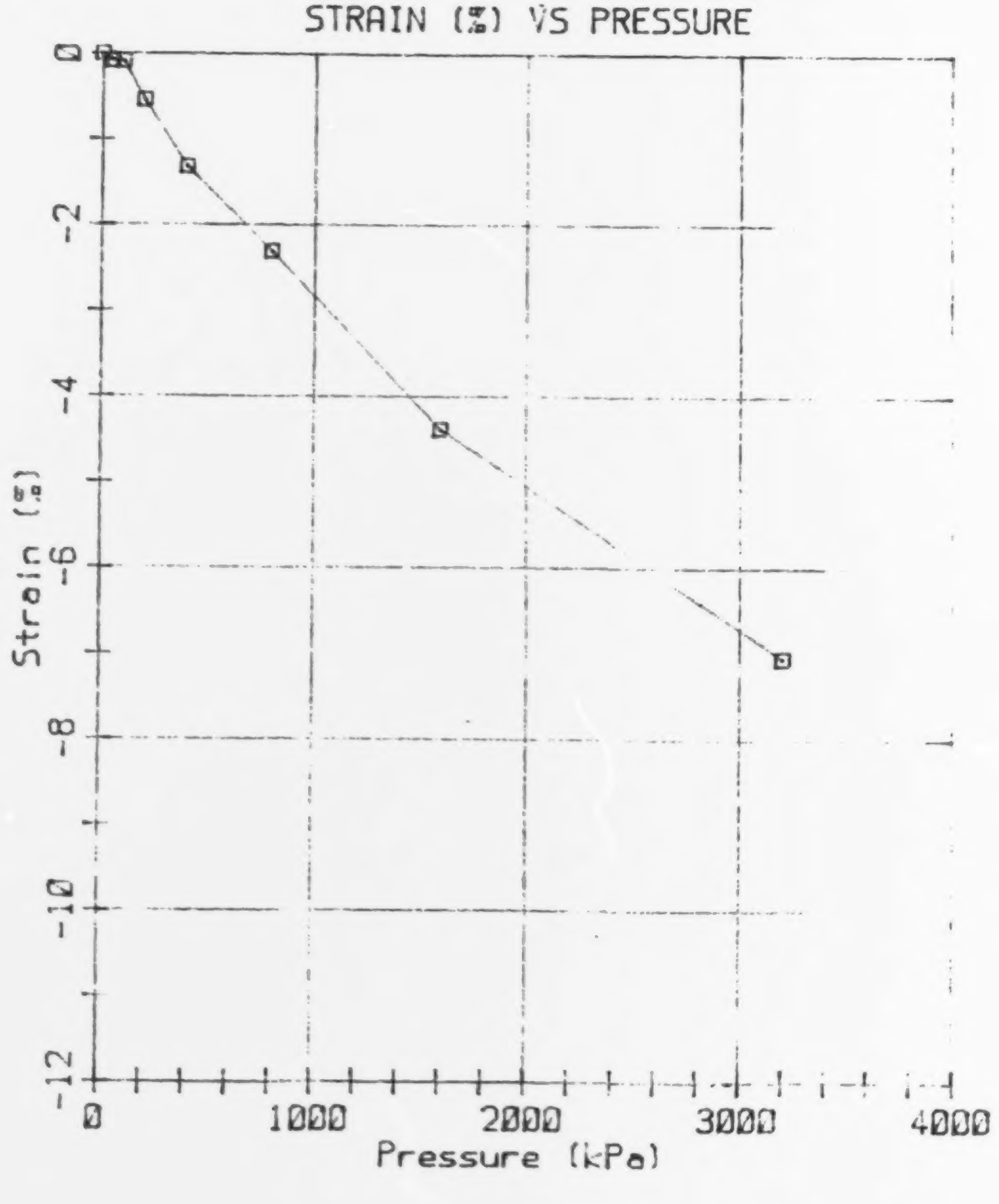
Tails Pile Instrumentation

PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 38.6-38.7

PROJECT NO: S85-1774



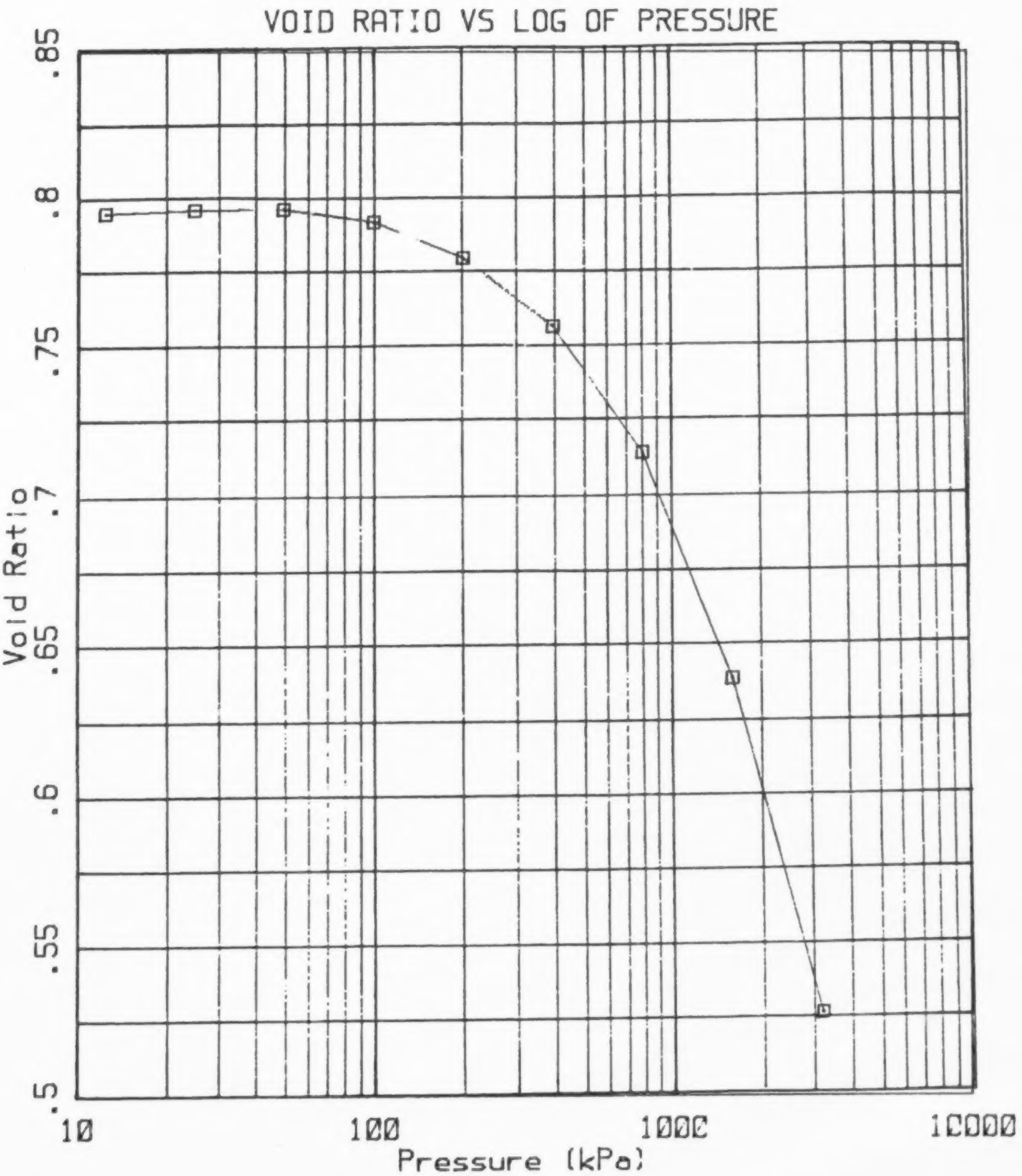
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 38.6-38.7

PROJECT NO: S85-1774



BBT Geotechnical Consultants Ltd.

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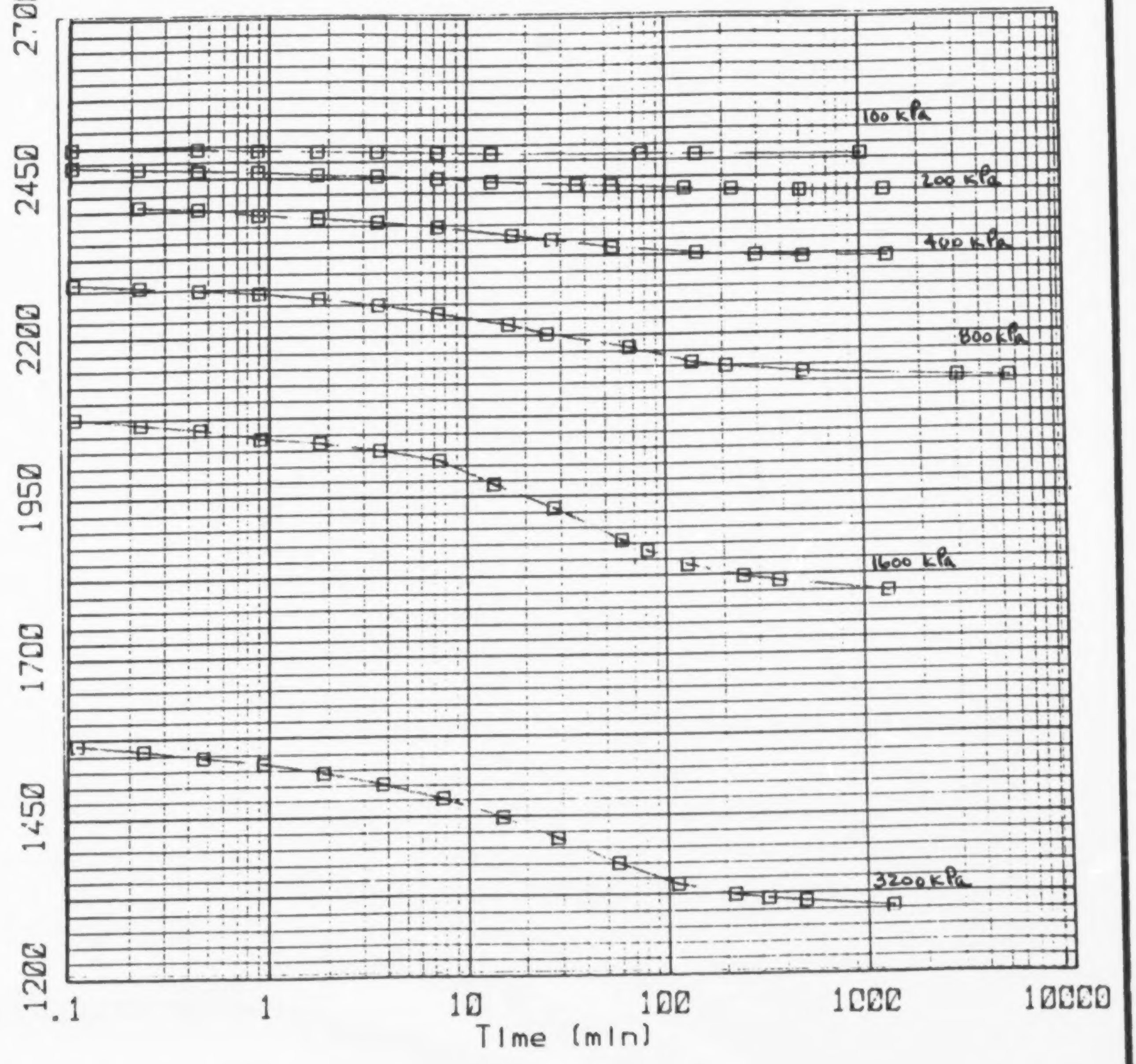
Tails Pile
Instrumentation

PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO. 58 DEPTH 41.0m

PROJECT NO
S85-1774



DIAL READING VS LOG TIME

BBT Geotechnical Consultants Ltd.

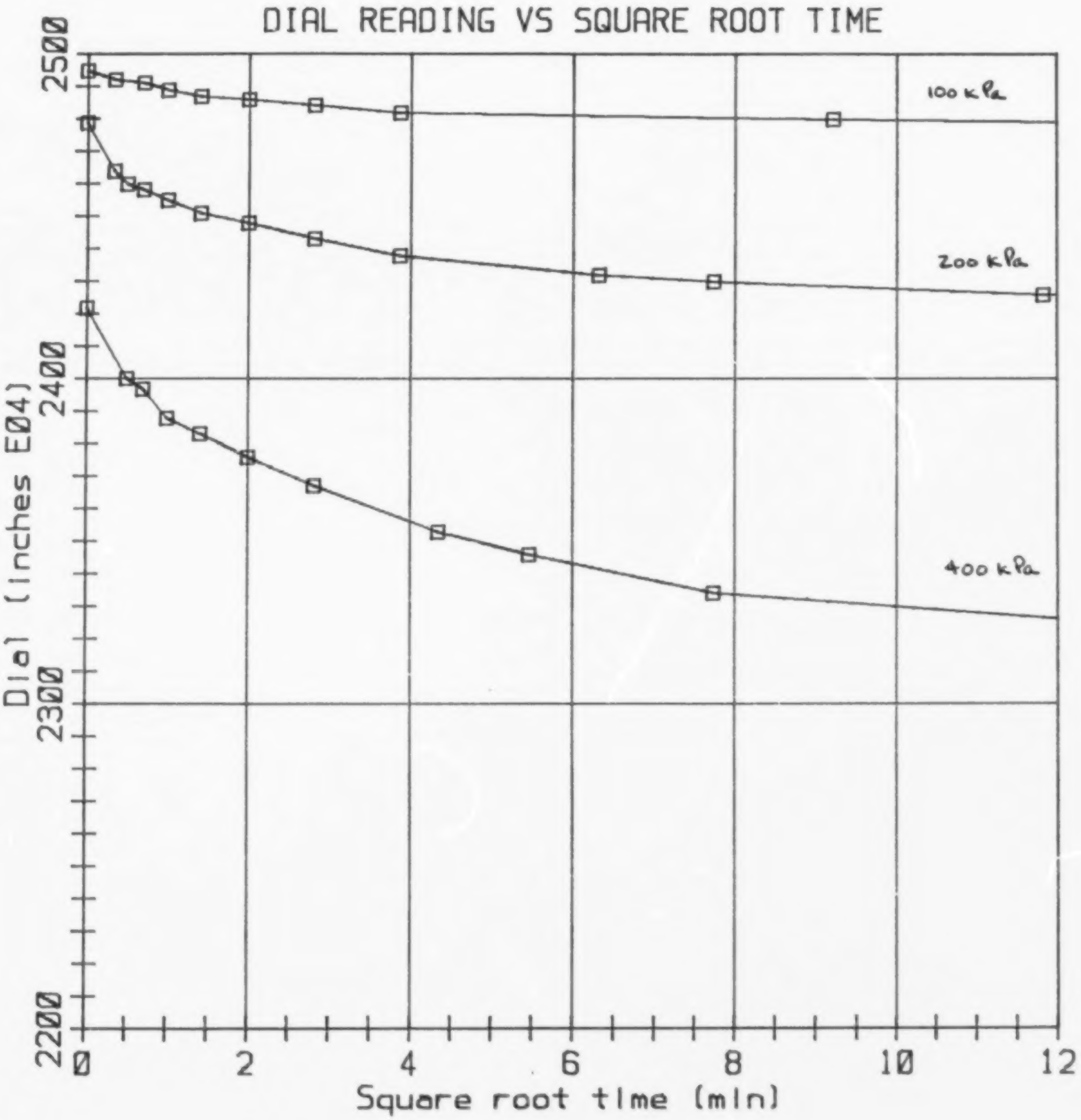
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO. 58 DEPTH 41.0 m

PROJECT NO
S85-1774



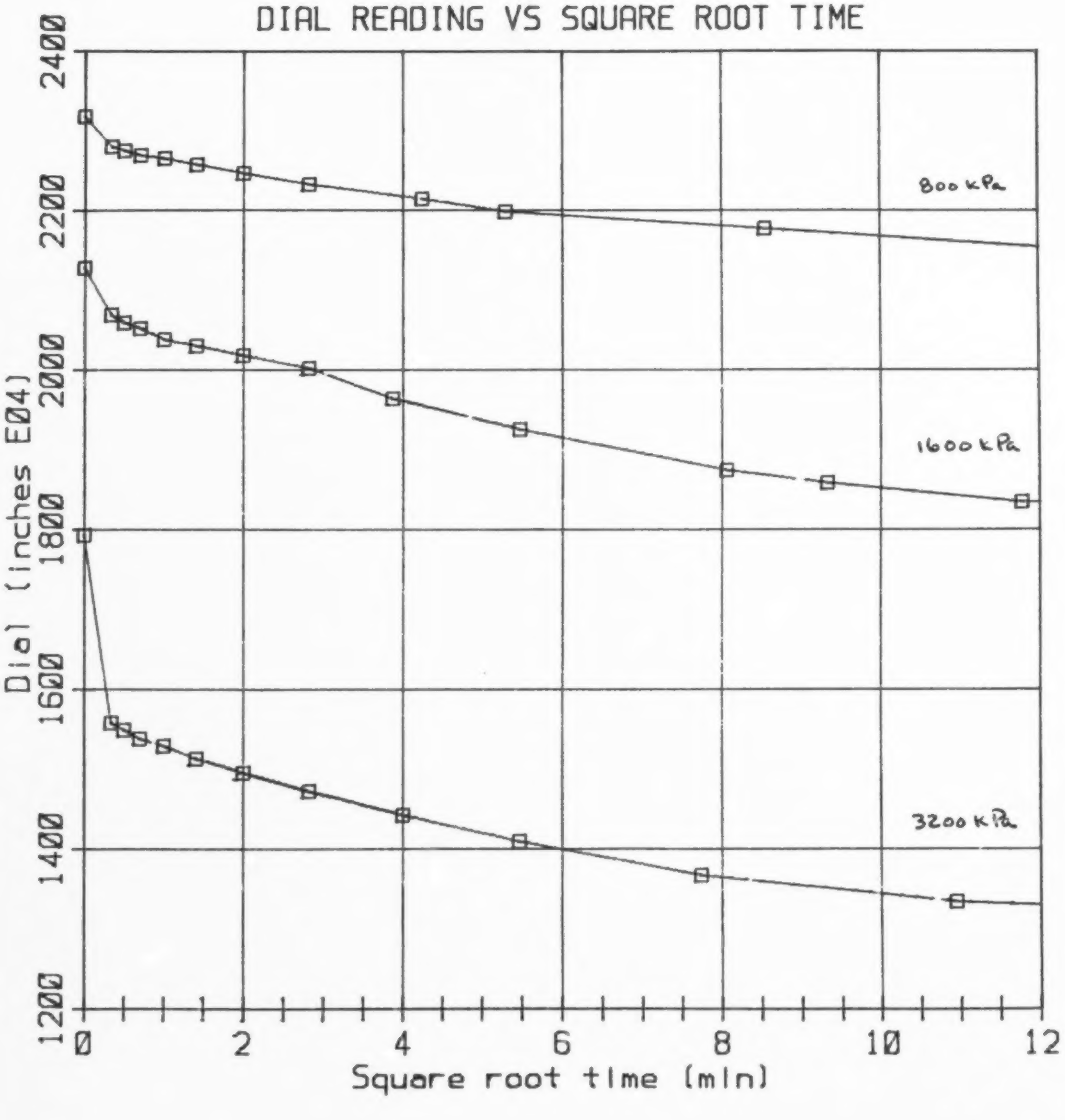
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 41.0 m

PROJECT NO:
S85-1774

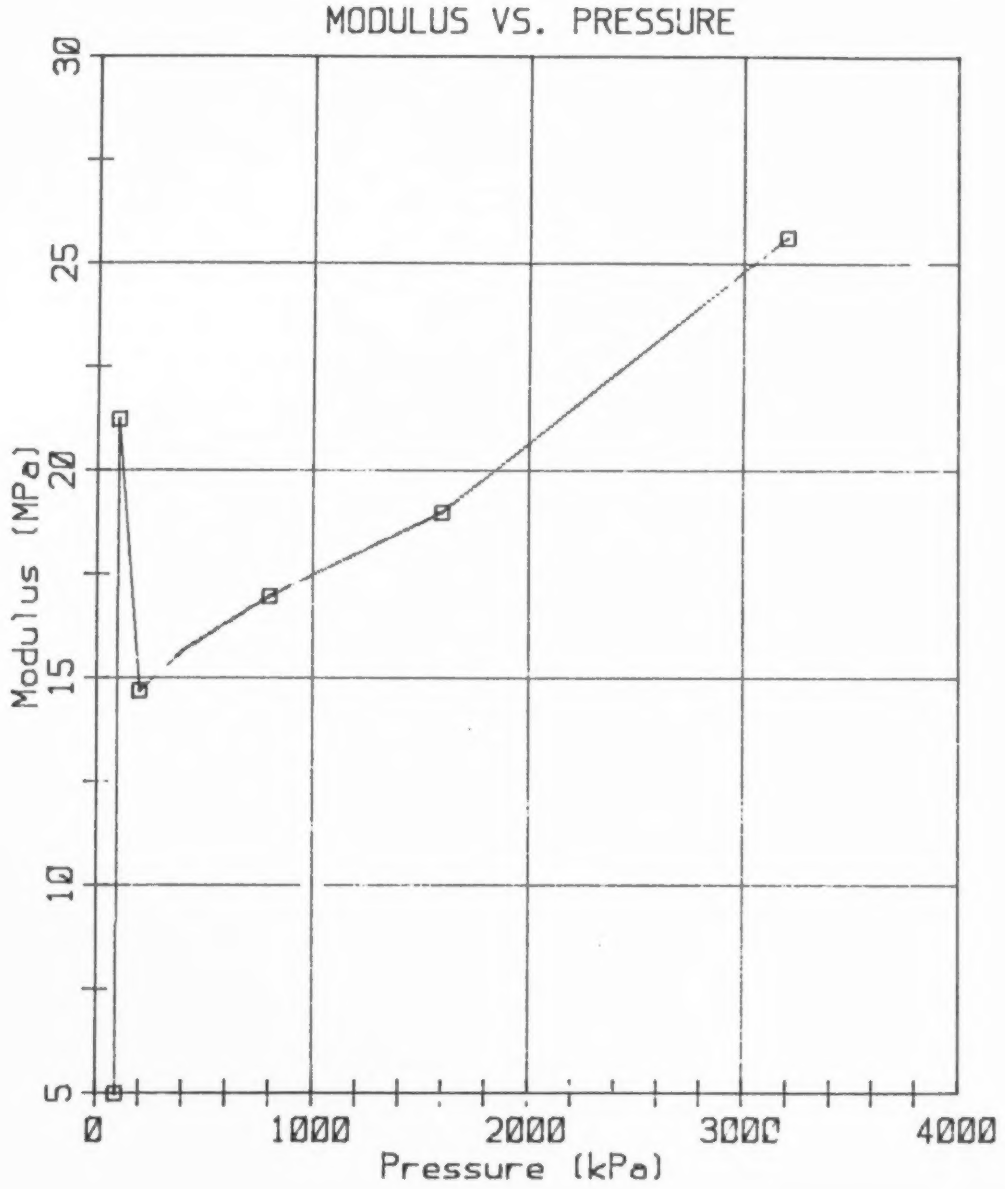


BBT Geotechnical Consultants Ltd
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58	DEPTH: 41.0m	PROJECT NO: S85-1774



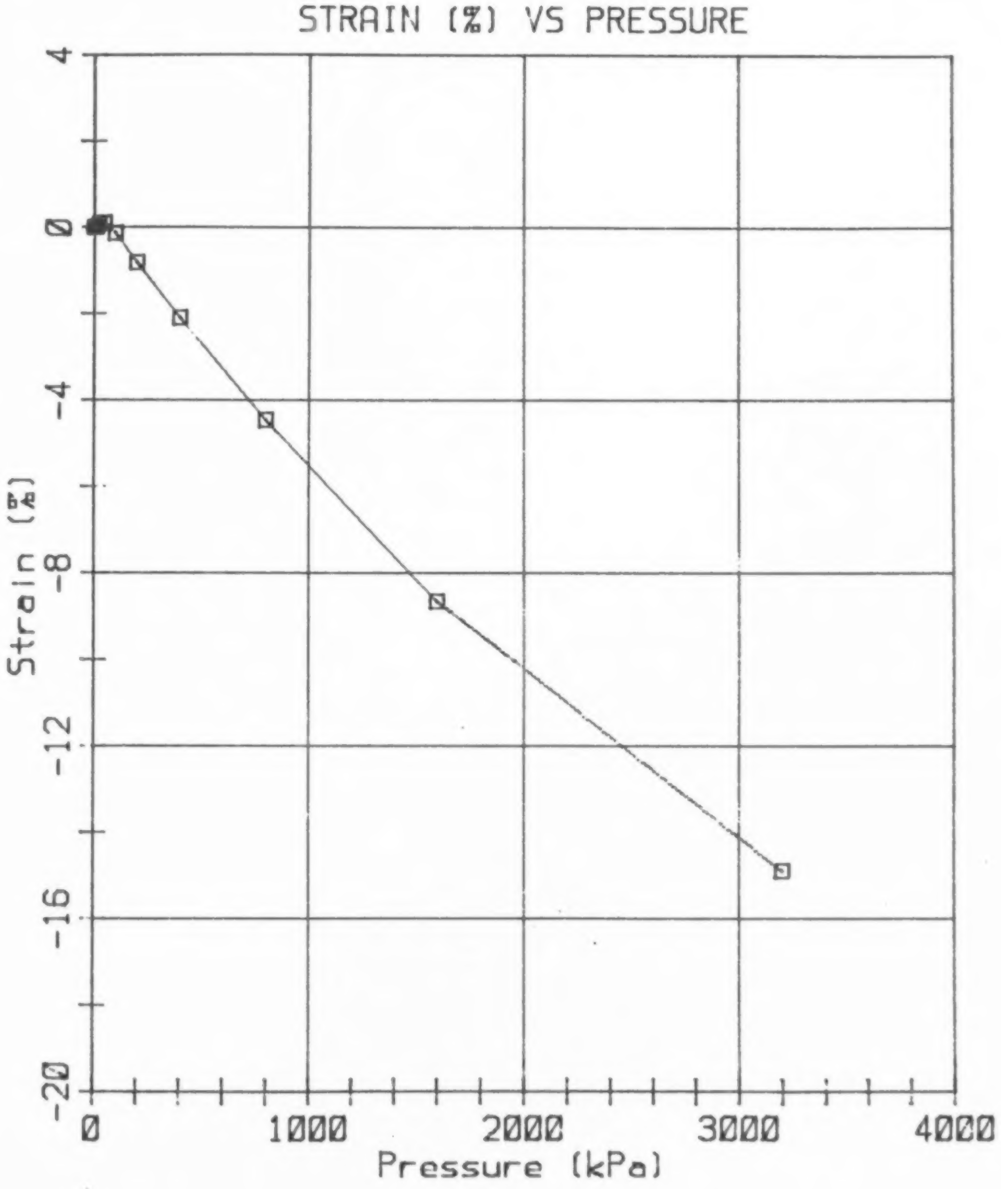
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

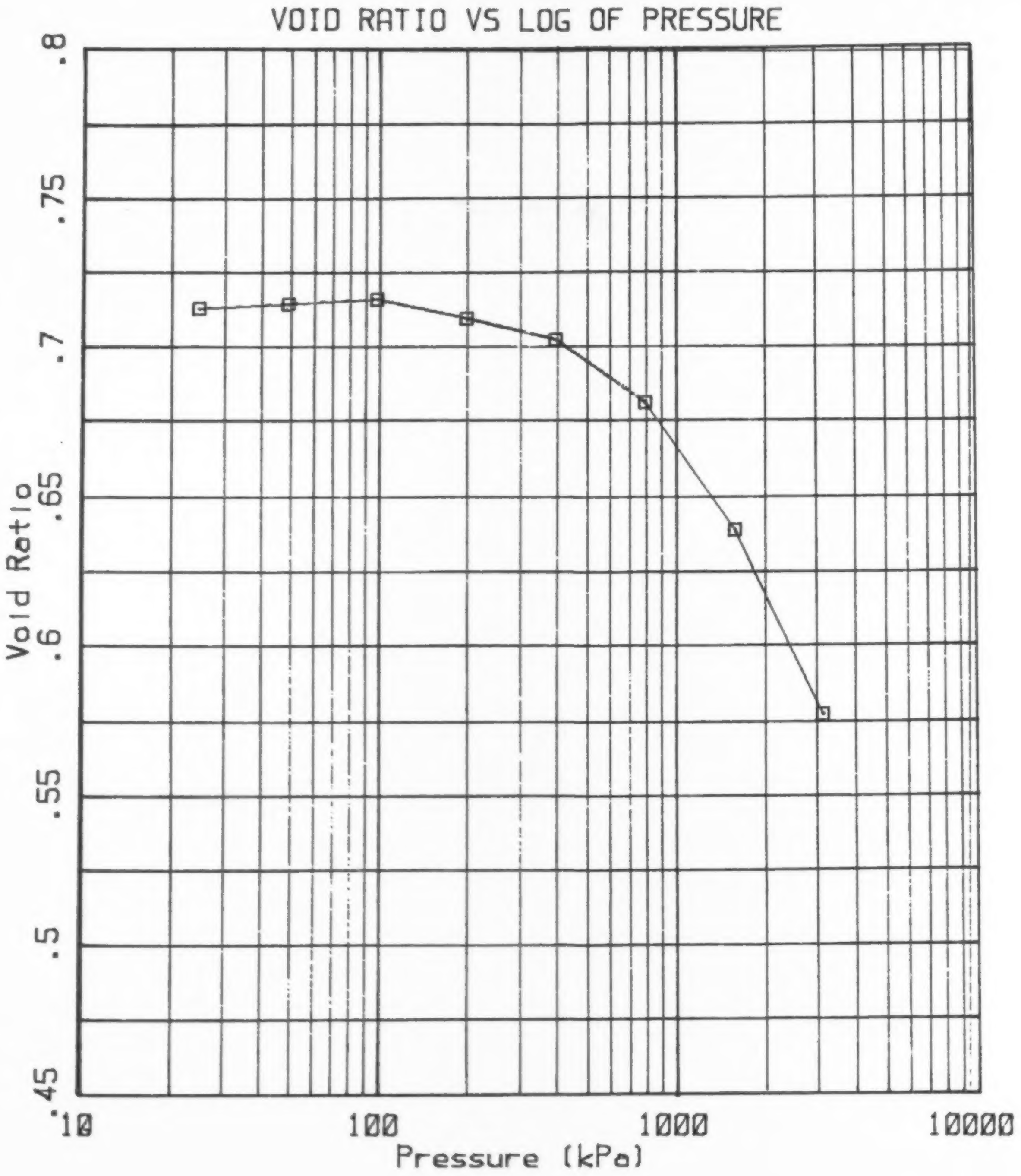
CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 41.0m

PROJECT NO
S85-1774



BBT Geotechnical Consultants Ltd. BBT GEOTECHNICAL CONSULTANTS LTD.	**Tails Pile Instrumentation** PCS ROCANVILLE
CONSOLIDATION TEST	TEST HOLE NO: 58 DEPTH: 41.0m PROJECT NO S85-1774



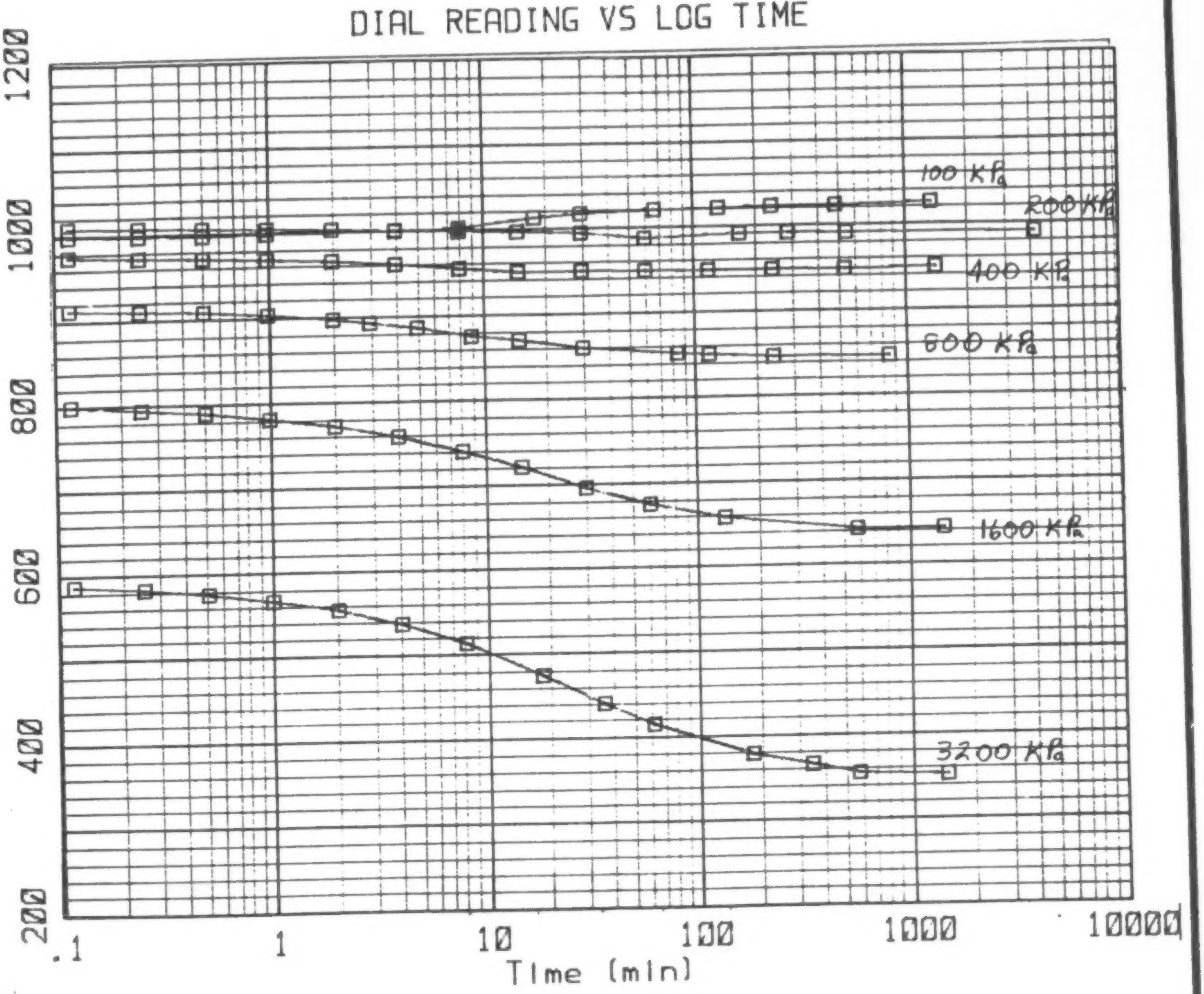
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 85-58 DEPTH: 42 m.

PROJECT NO: S85-1774


DIAL READING VS LOG TIME

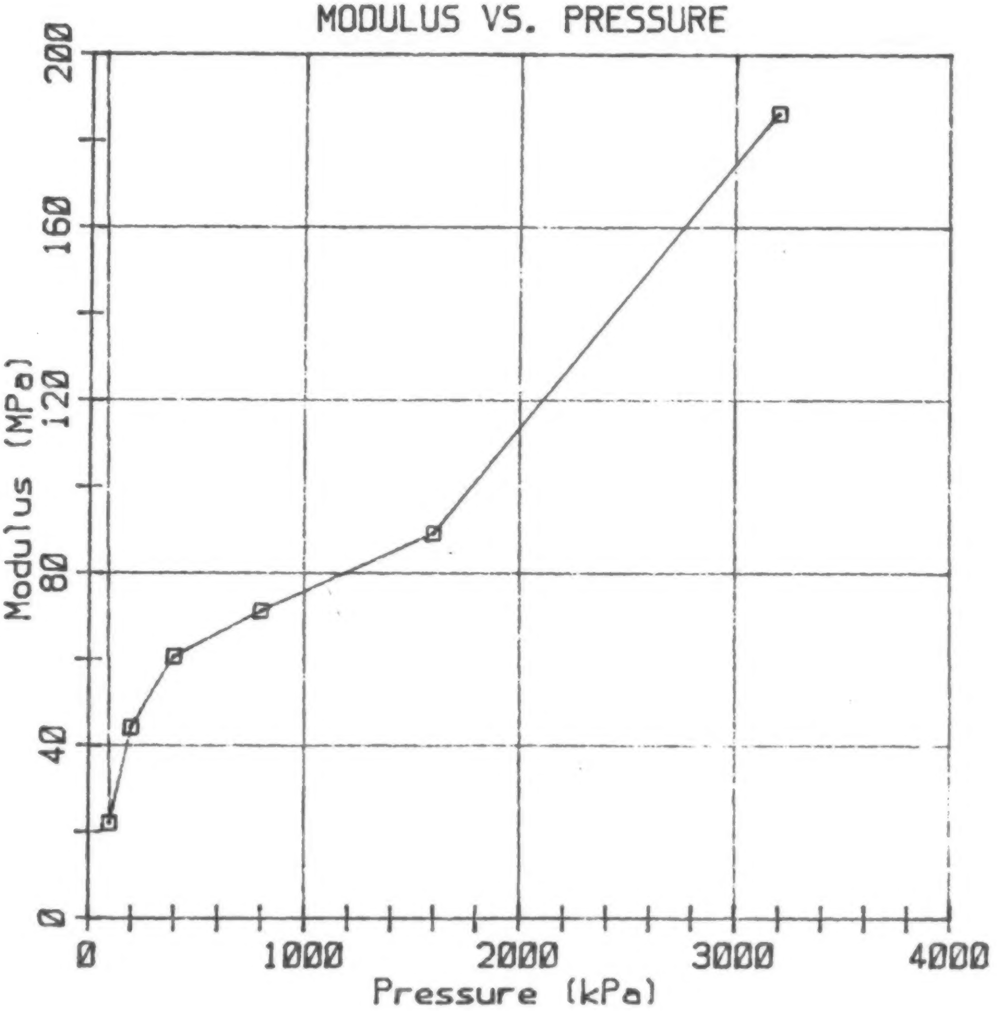
Geotechnical Consultants Ltd
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

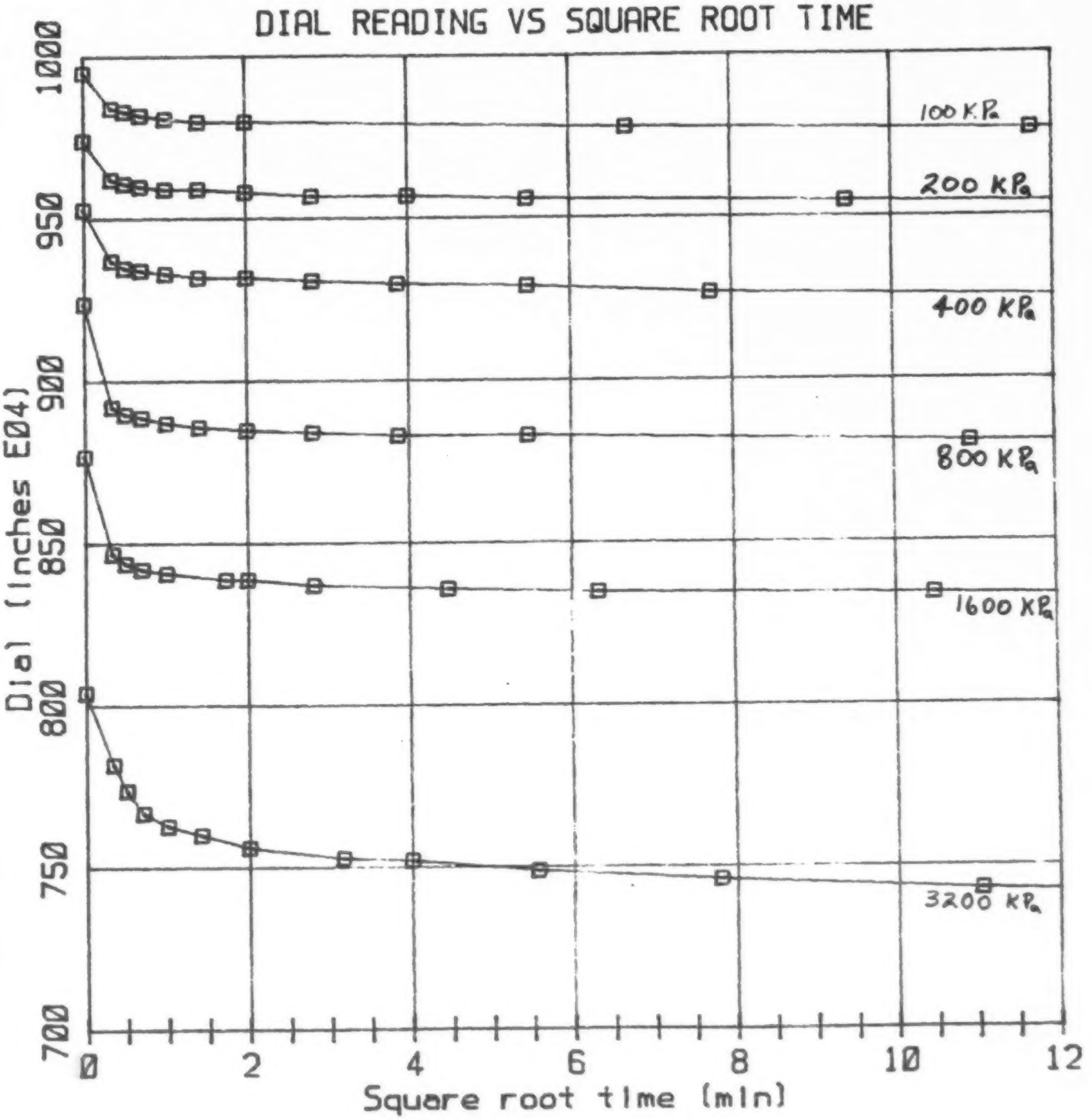
CONSOLIDATION TEST

TEST HOLE NO: 85-5B DEPTH: 42 m

PROJECT NO: S85-1774



BBT Geotechnical Consultants Ltd. BBT GEOTECHNICAL CONSULTANTS LTD.	**Tails Pile Instrumentation** PCS ROCANVILLE	
CONSOLIDATION TEST	TEST HOLE NO: 6B DEPTH: 43.0m	PROJECT NO: S85-1774



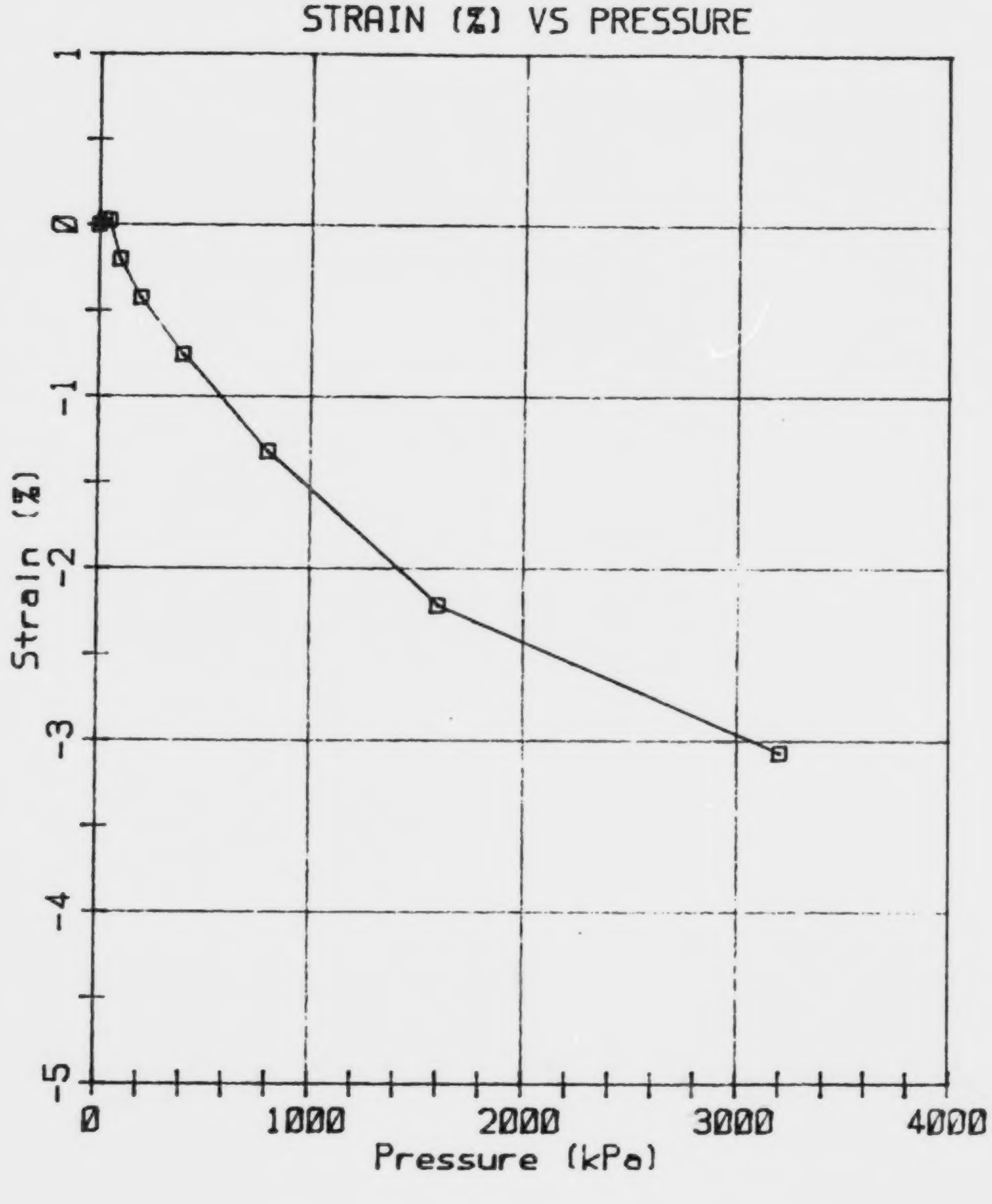
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 43.0m

PROJECT NO: S85-1774



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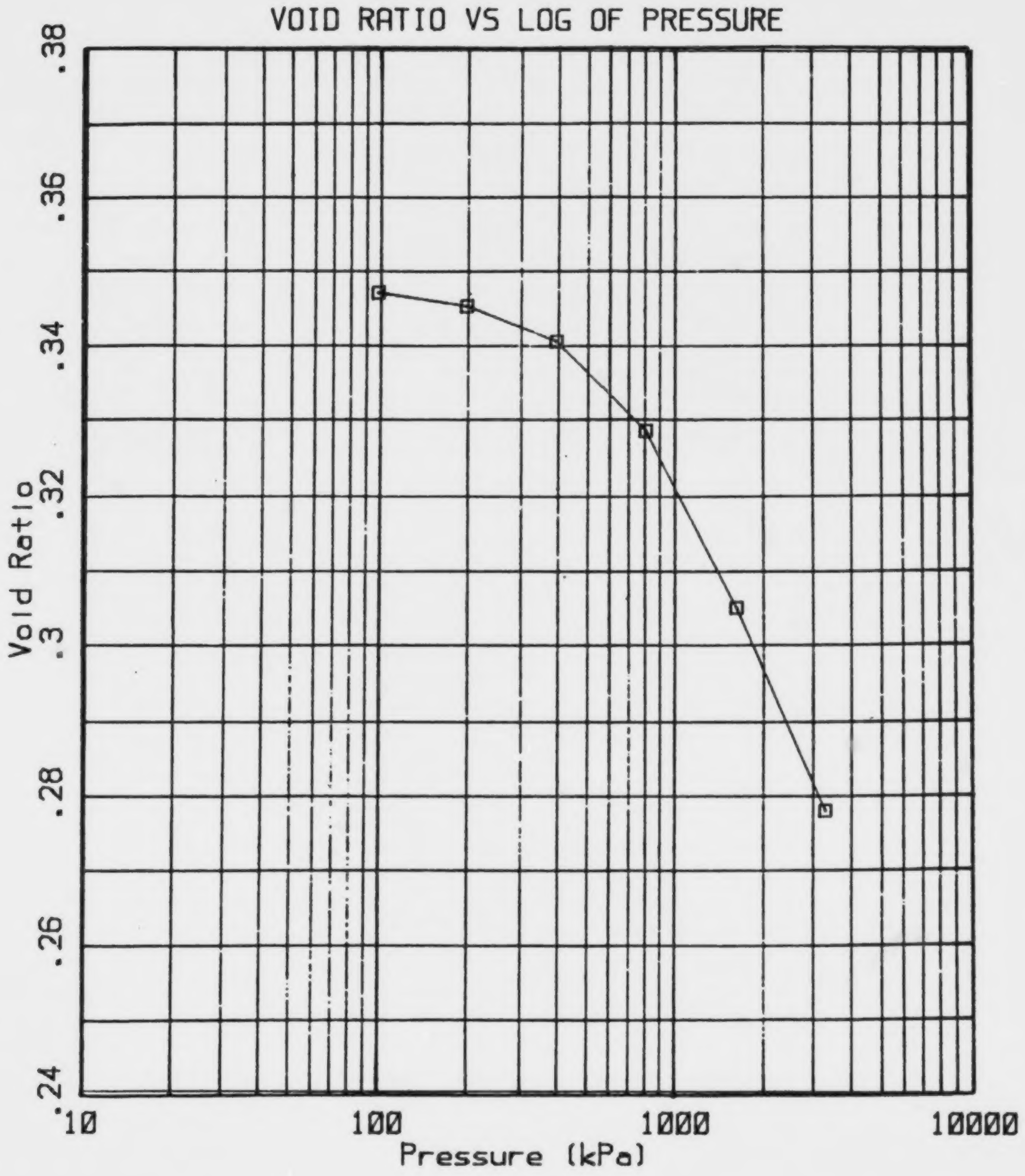
Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 43.0 m

PROJECT NO: S85-1774



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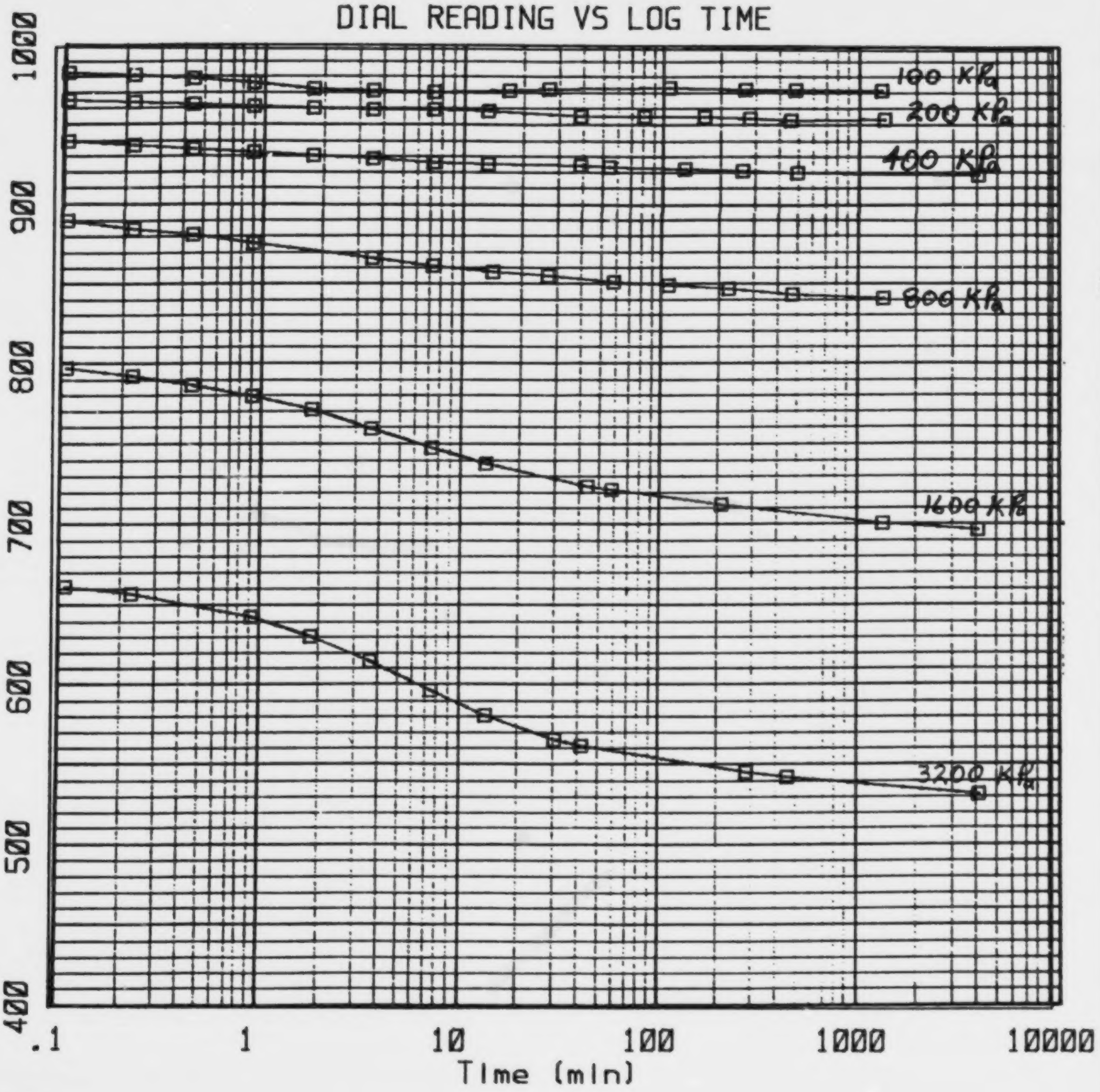
CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 50.6–50.7m

PROJECT NO: S85-1774



DIAL READING VS LOG TIME

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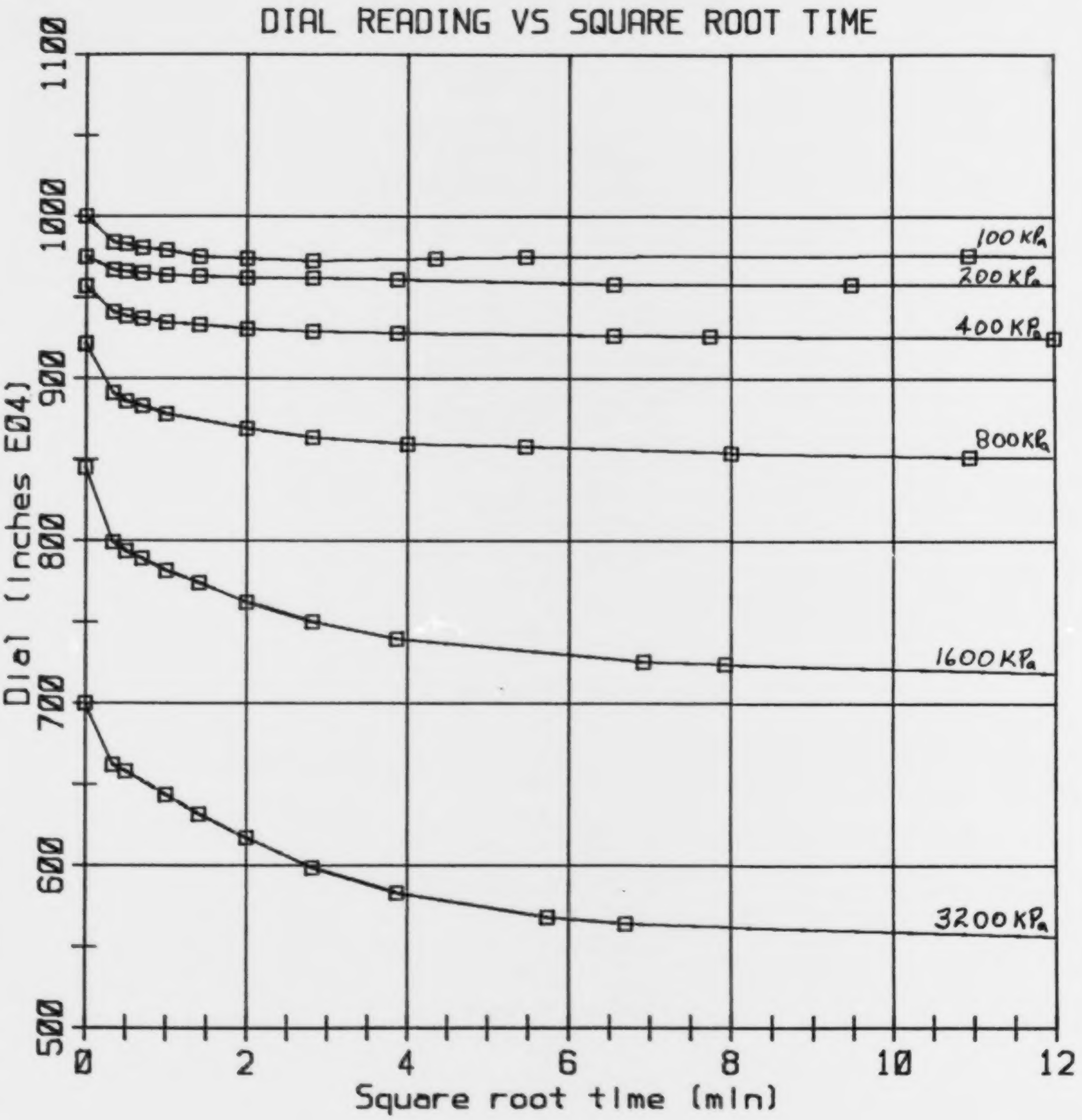
Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 60 DEPTH: 50.6-50.7m

PROJECT NO: S85-1774



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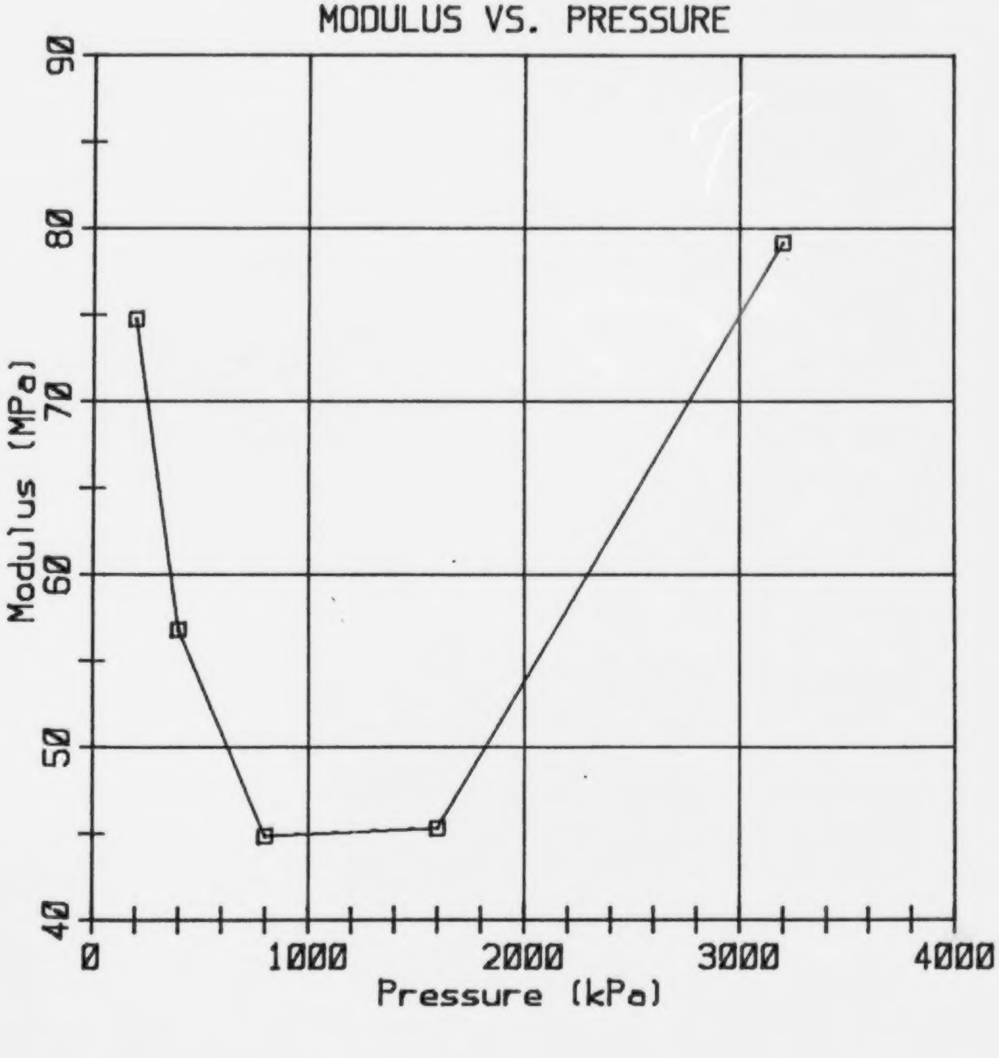
Tails Pile Instrumentation
PCS ROCANVILLE

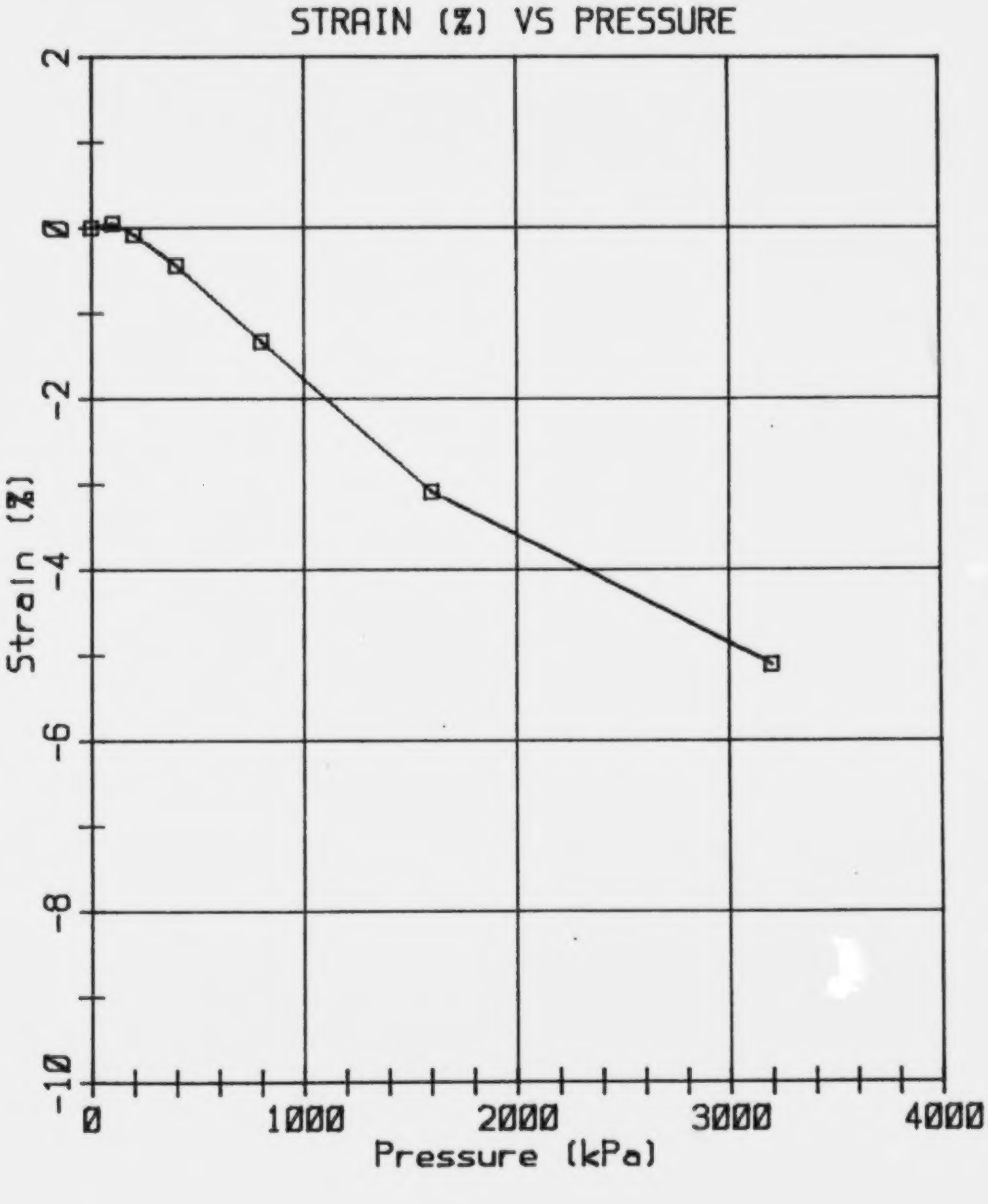
CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 50.6-50.7m

PROJECT NO: S85-1774



BBT Geotechnical Consultants Ltd. BBT GEOTECHNICAL CONSULTANTS LTD.	**Tails Pile Instrumentation** PCS ROCANVILLE
CONSOLIDATION TEST	TEST HOLE NO: 68 DEPTH: 50.6–50.7m PROJECT NO: S85-1774



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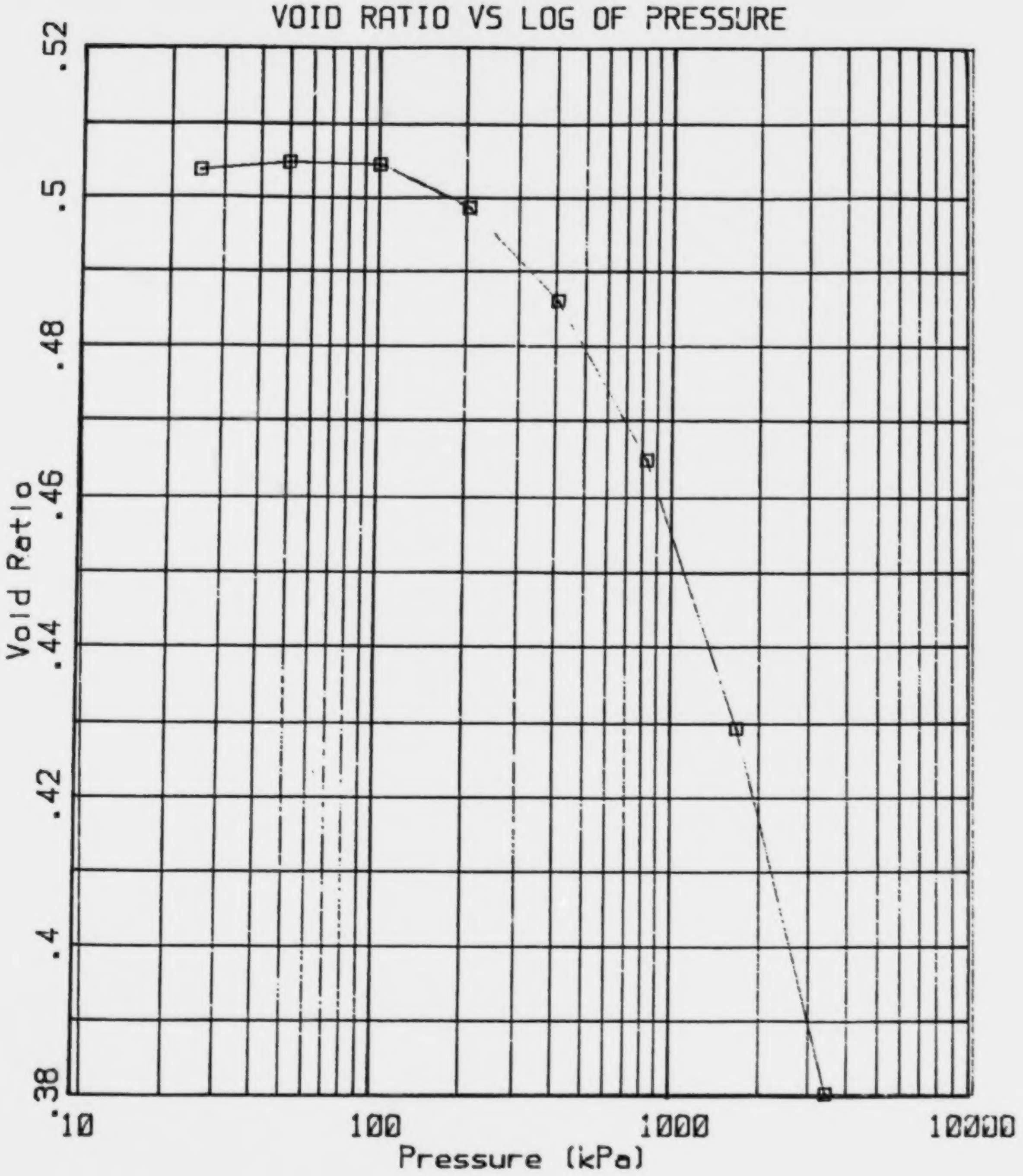
Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 50.6–50.7m

PROJECT NO: S85-1774


VOID RATIO VS LOG OF PRESSURE

BBT Geotechnical Consultants Ltd.
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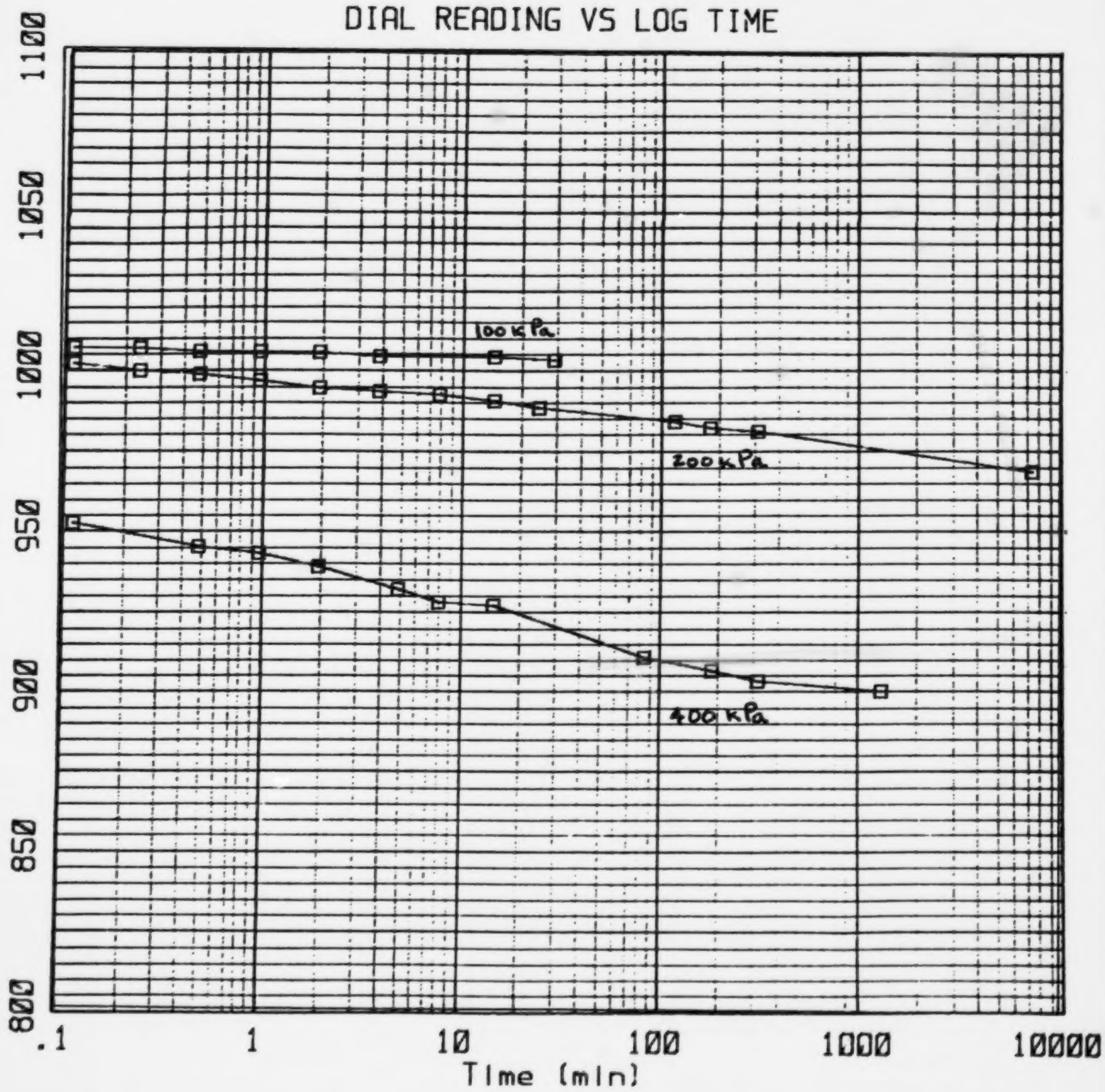
Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO. 68 DEPTH 57.9m

PROJECT NO
S85-1774



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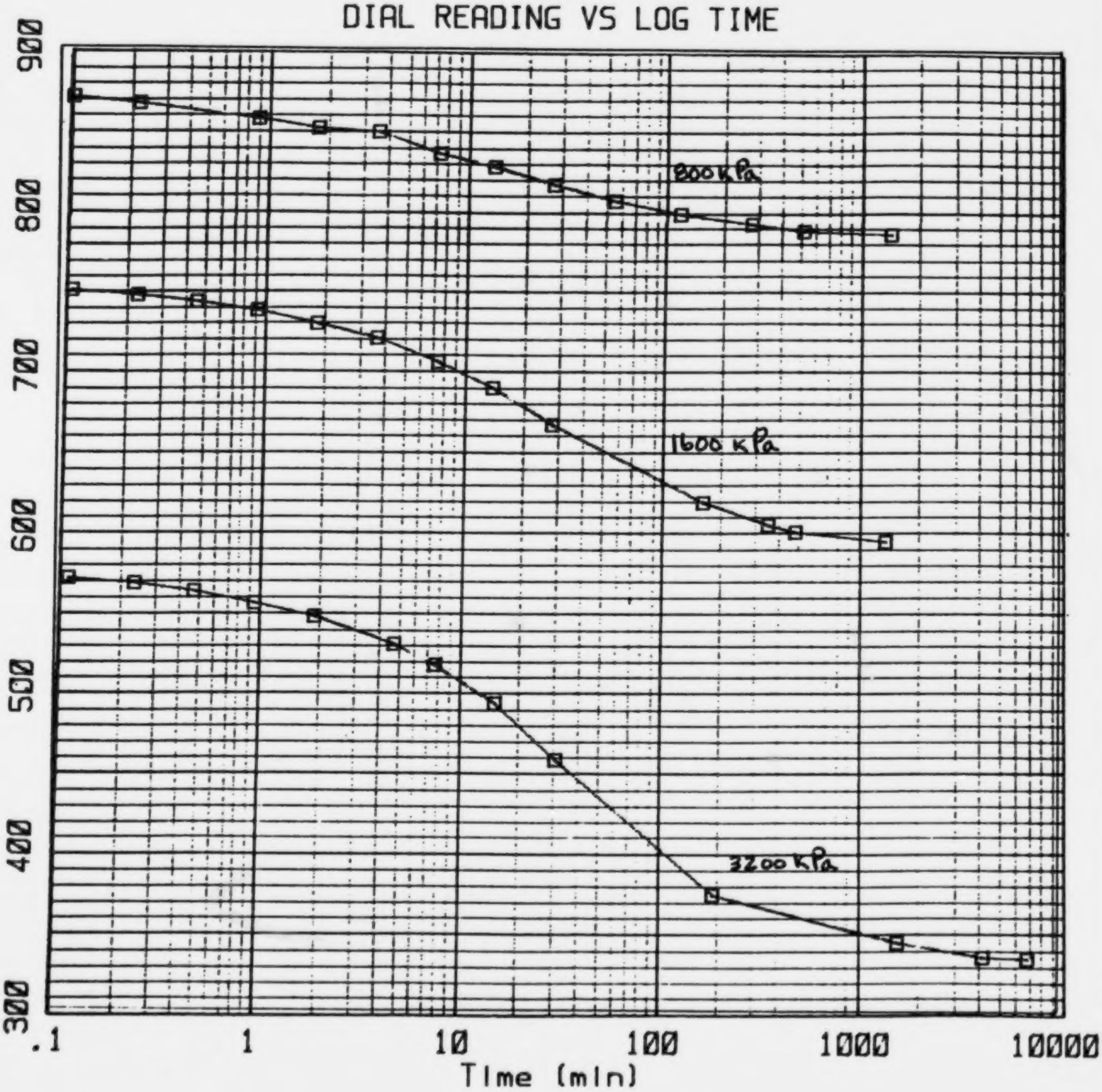
Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 57.9m

PROJECT NO: S85-1774



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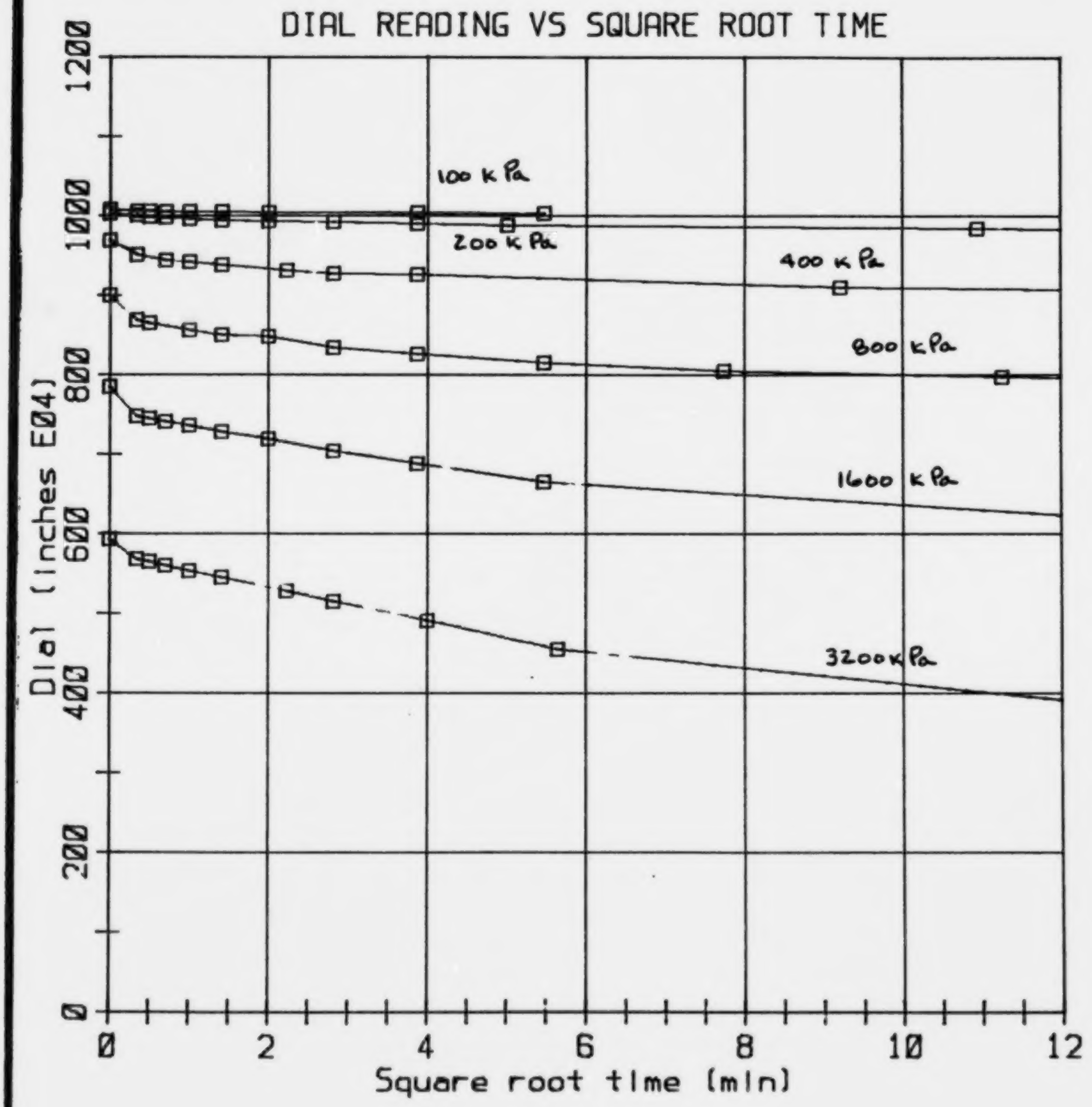
Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68	DEPTH: 57.9m	PROJECT NO: S85-1774



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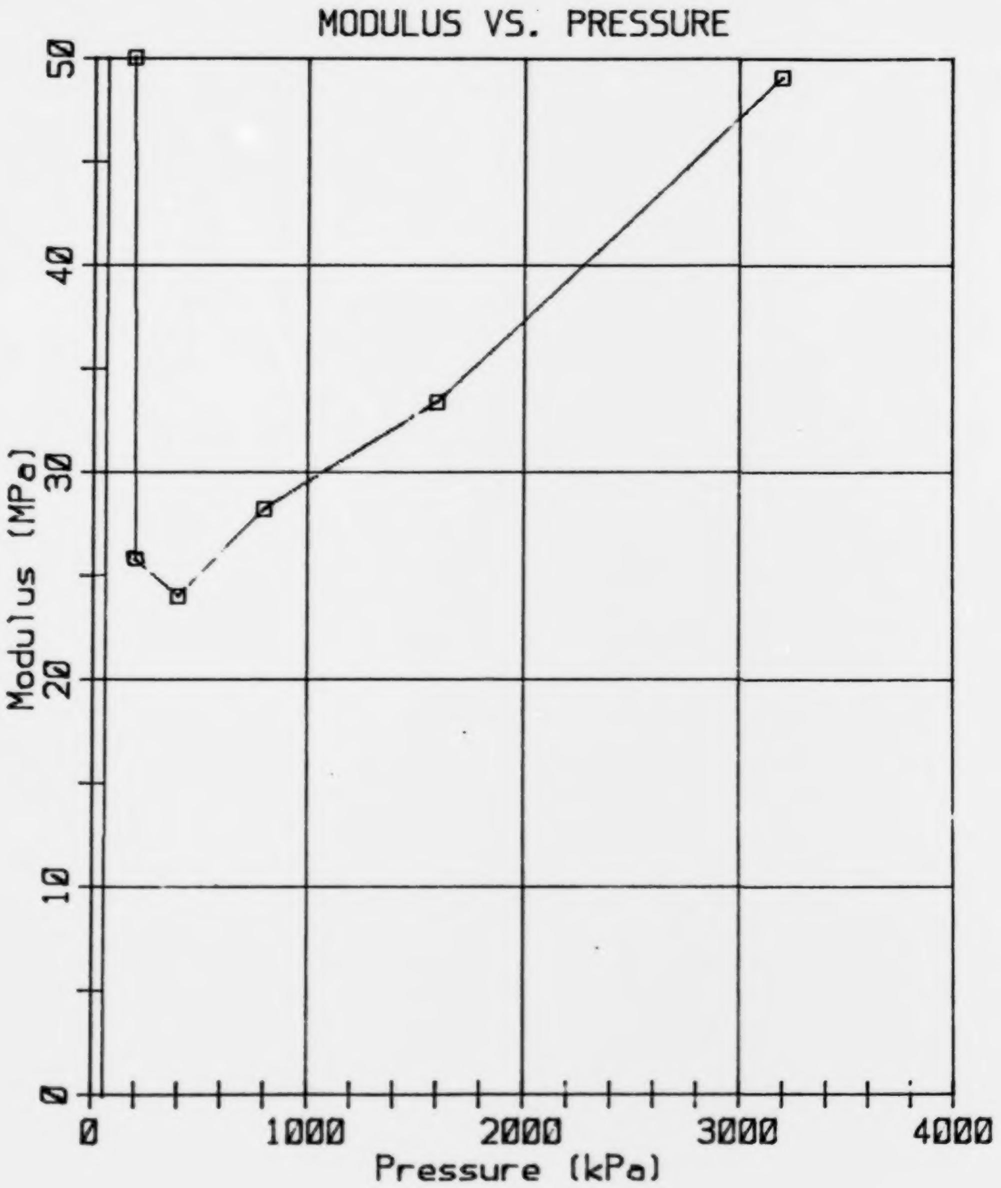
Tails Pile Instrumentation

PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 6B DEPTH: 57.9m

PROJECT NO: S85-1774



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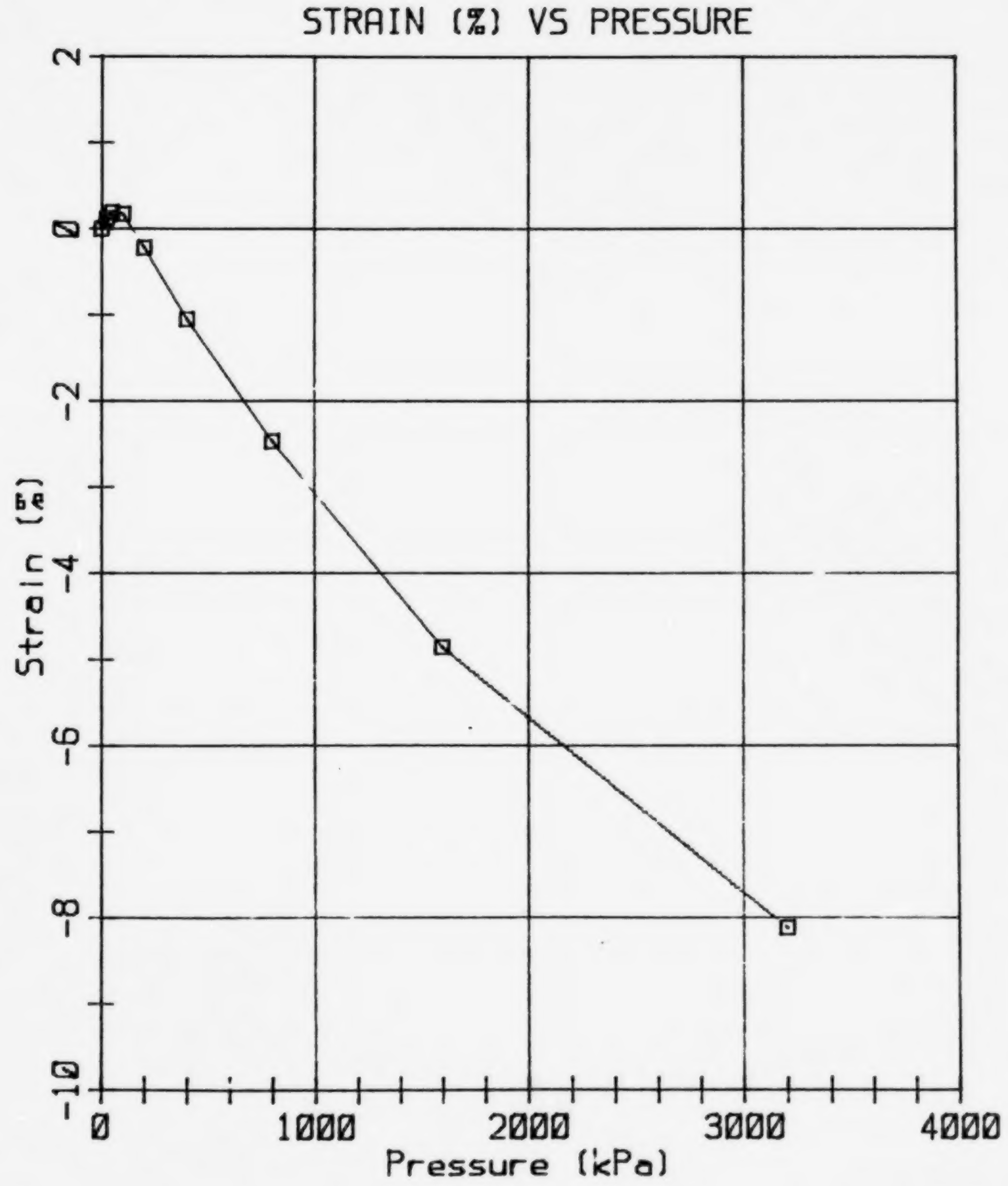
Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 57.9m

PROJECT NO: S85-1774



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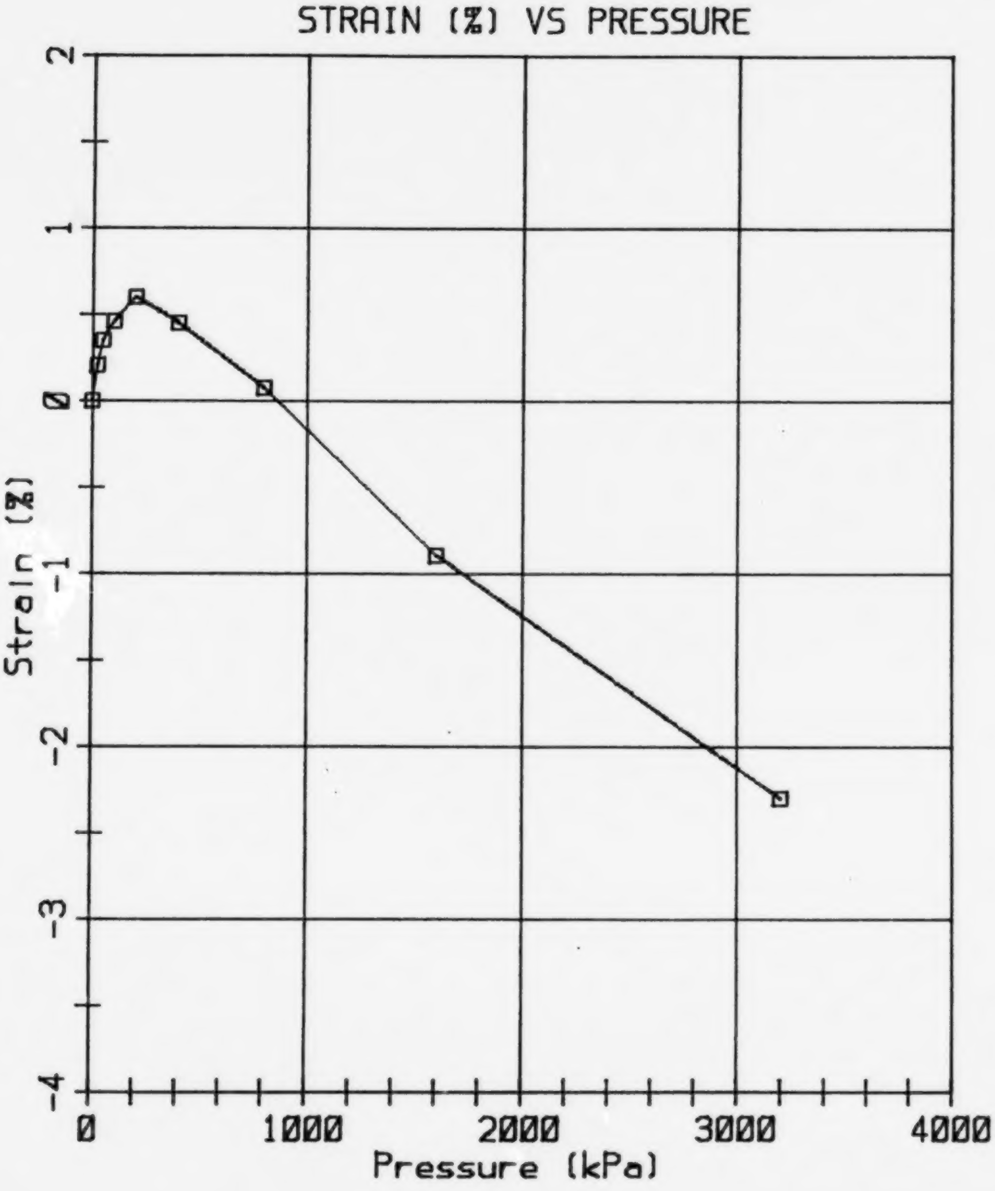
Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 57.9m

PROJECT NO: S85-1774



BBT Geotechnical Consultants Ltd.
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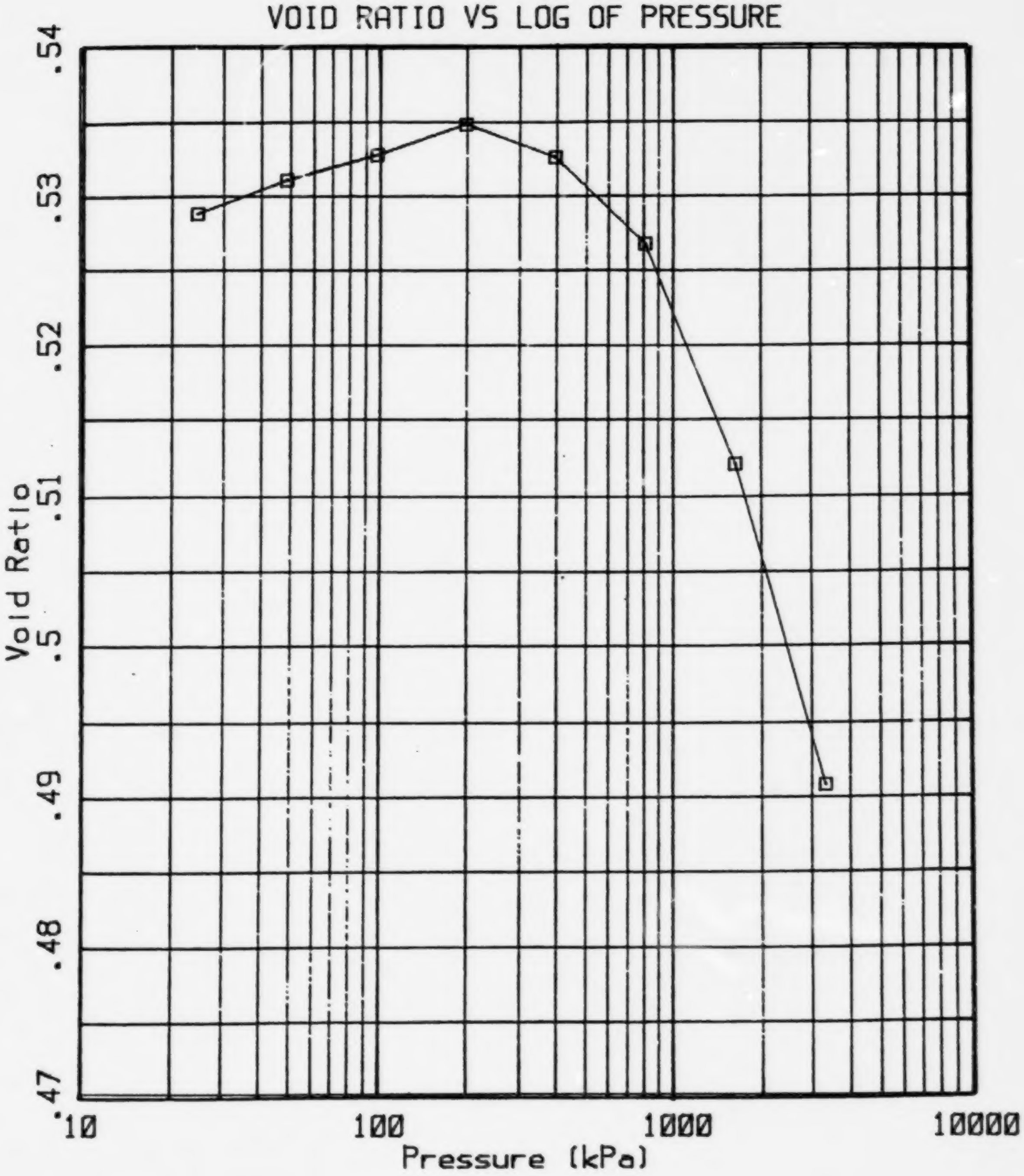
Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 60 DEPTH: 60.4 m

PROJECT NO: S85-1774



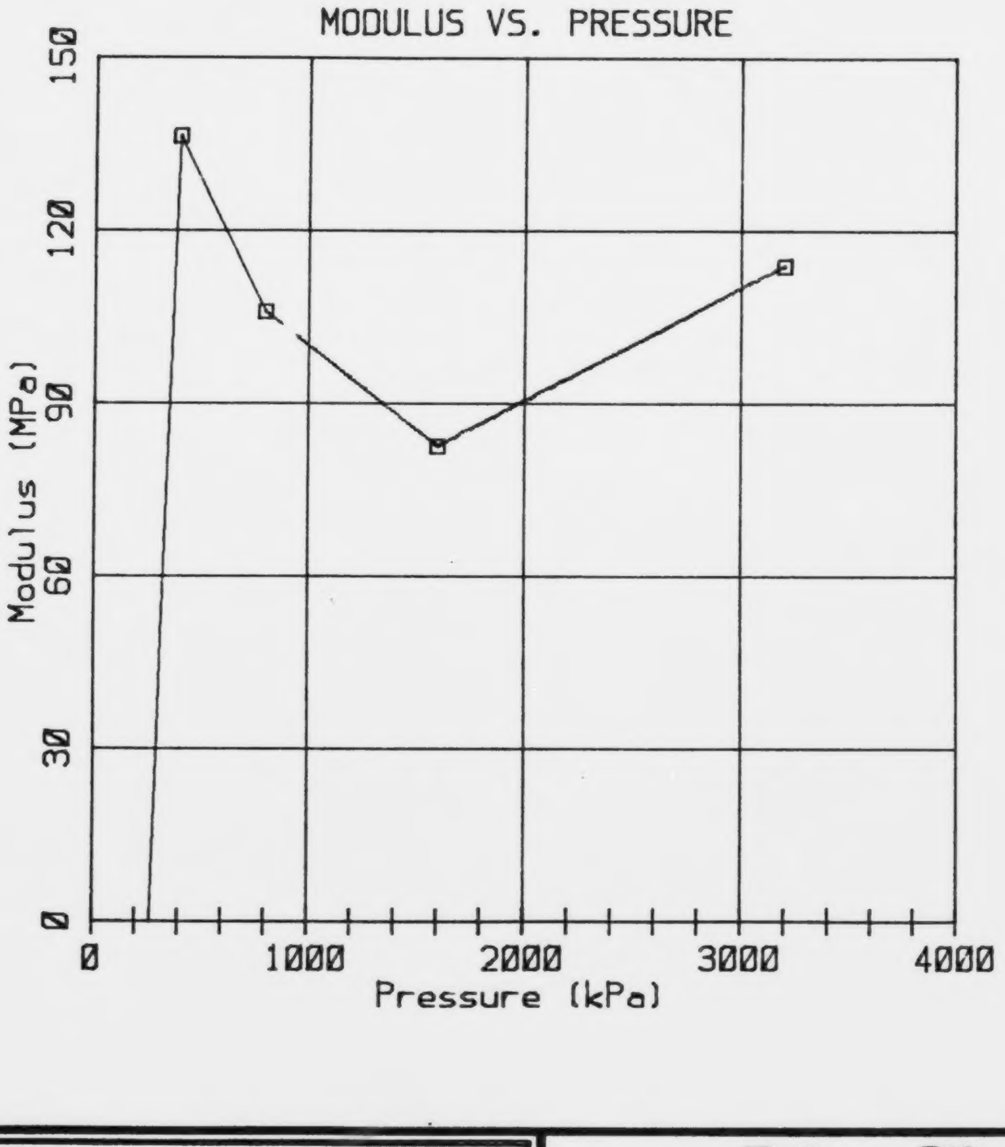
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 68.4m

PROJECT NO: S85-1774



Geotechnical Consultants Ltd.
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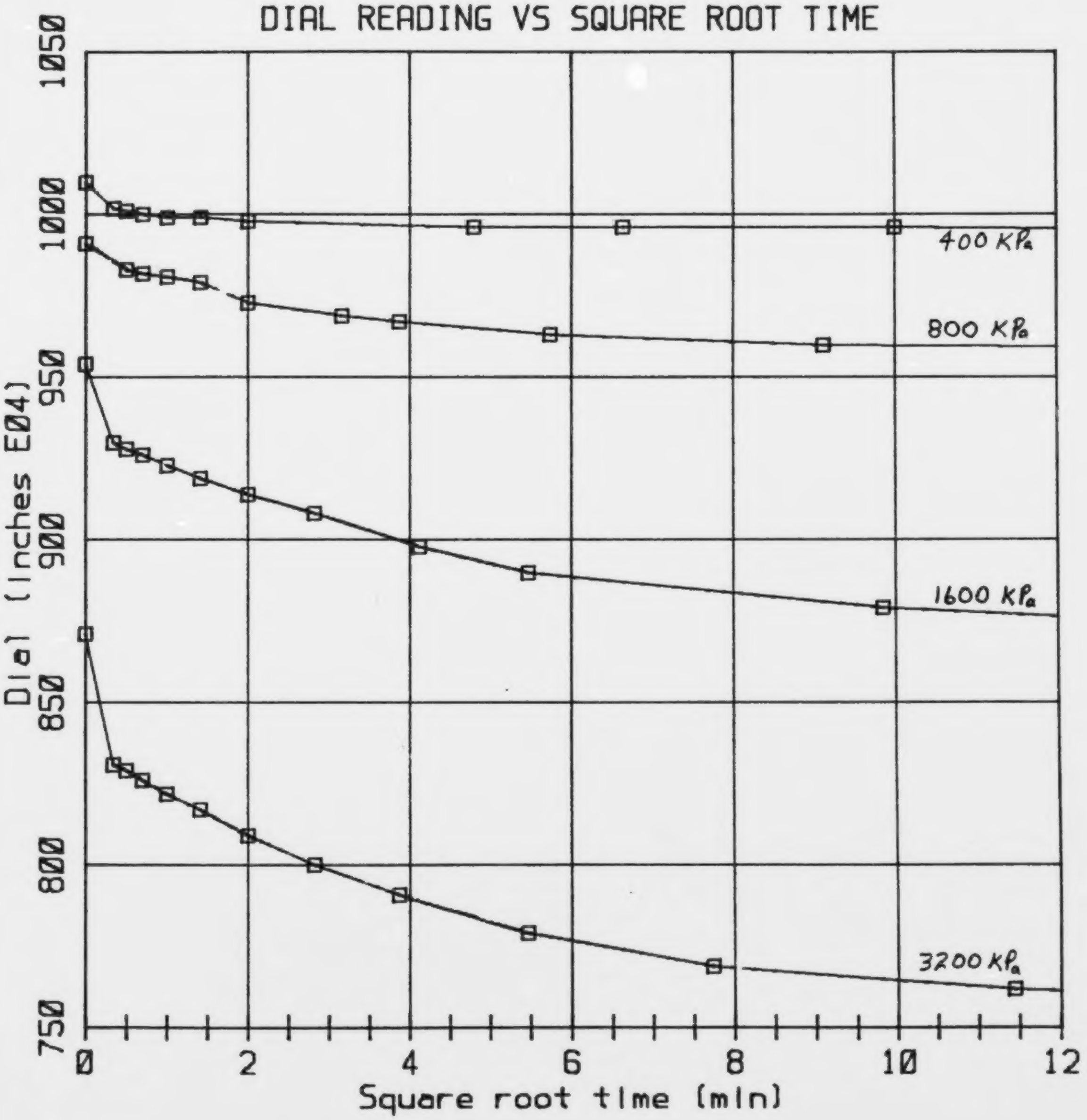
Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 68.4m

PROJECT NO:
S85-1774


DIAL READING VS SQUARE ROOT TIME

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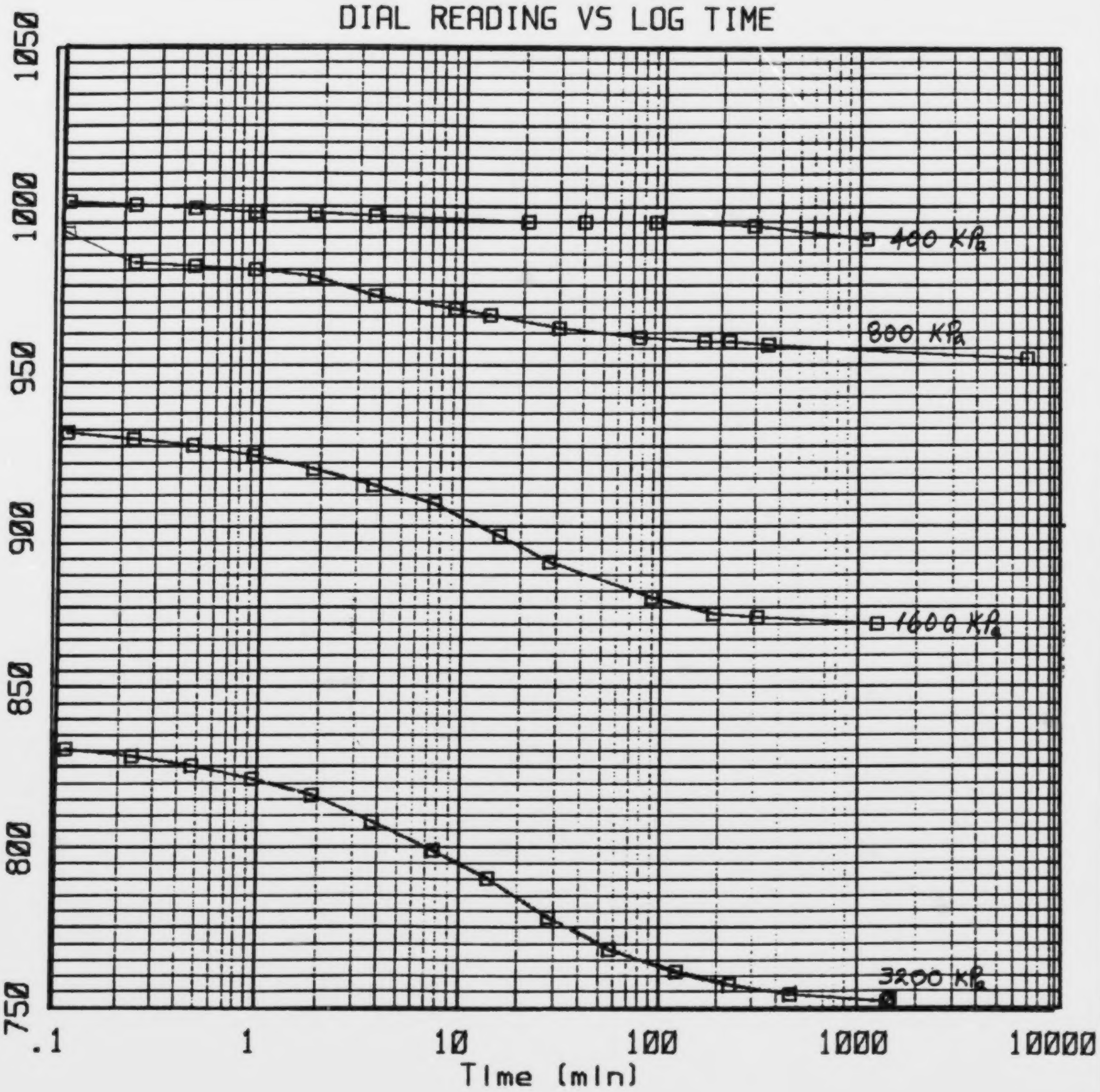
Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 68.4m

PROJECT NO: S85-1774



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Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

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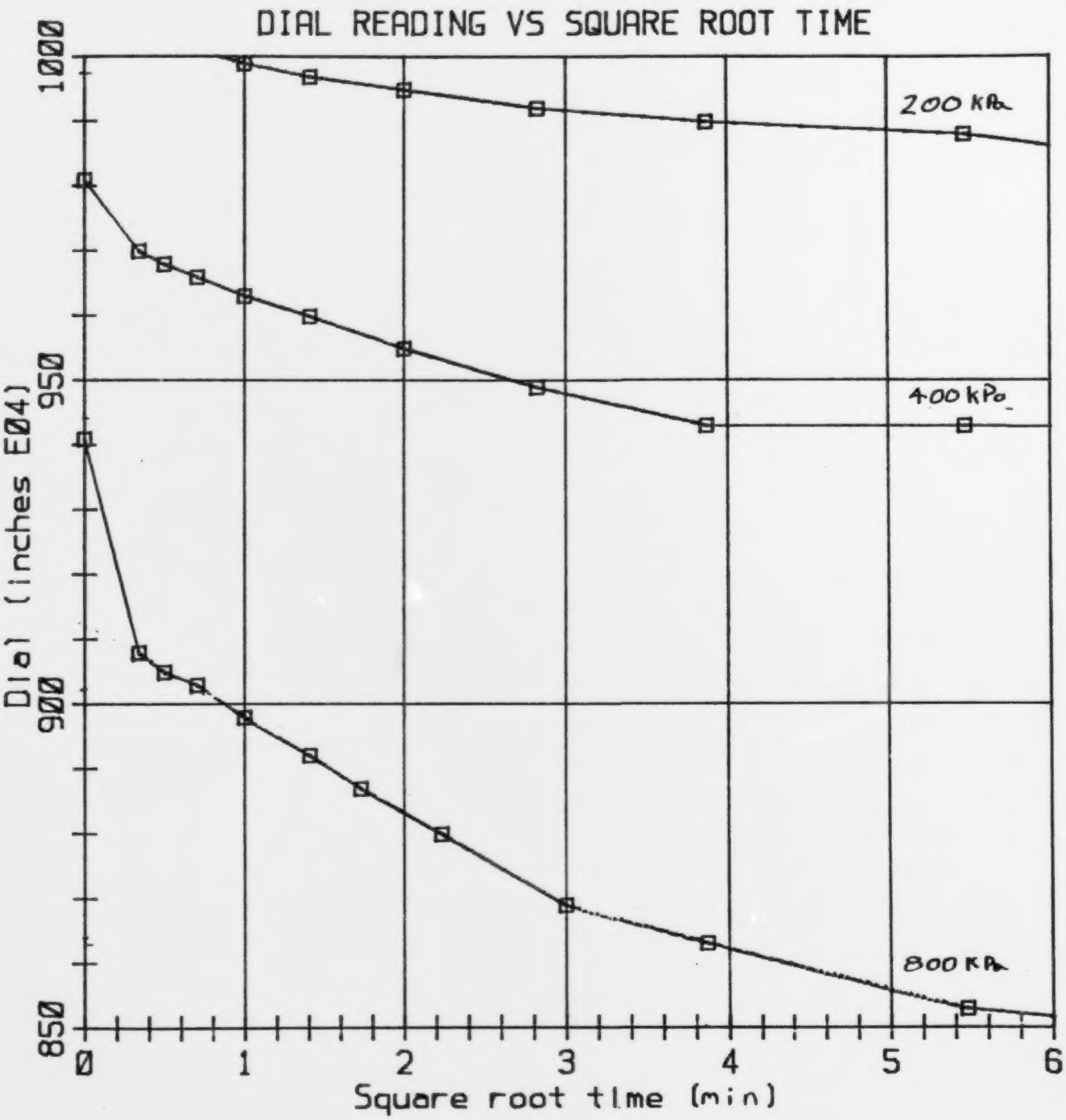
PROJECT NO: S85-1774



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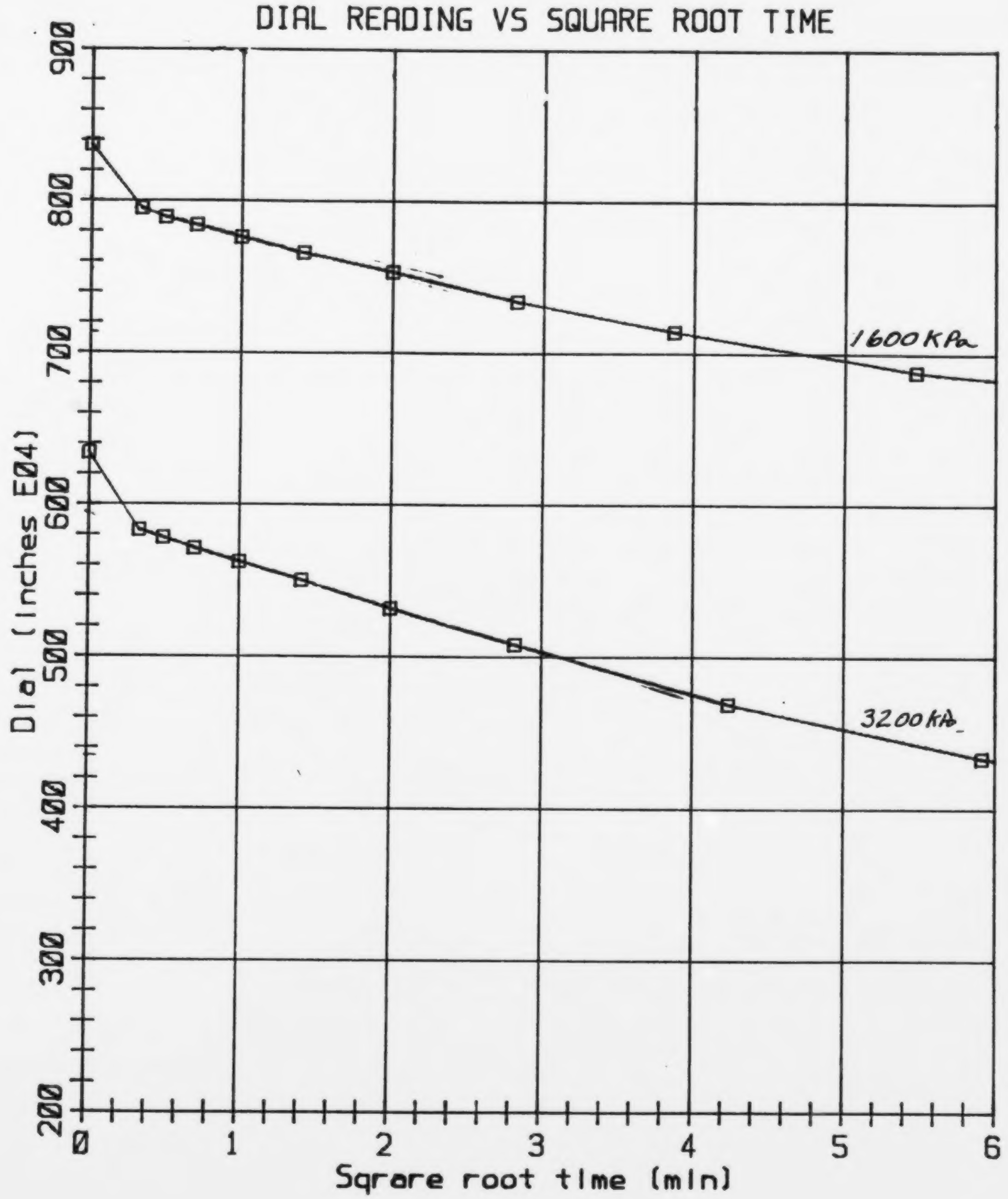
Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 85-68 DEPTH: 42 m

PROJECT NO:
S85-1774



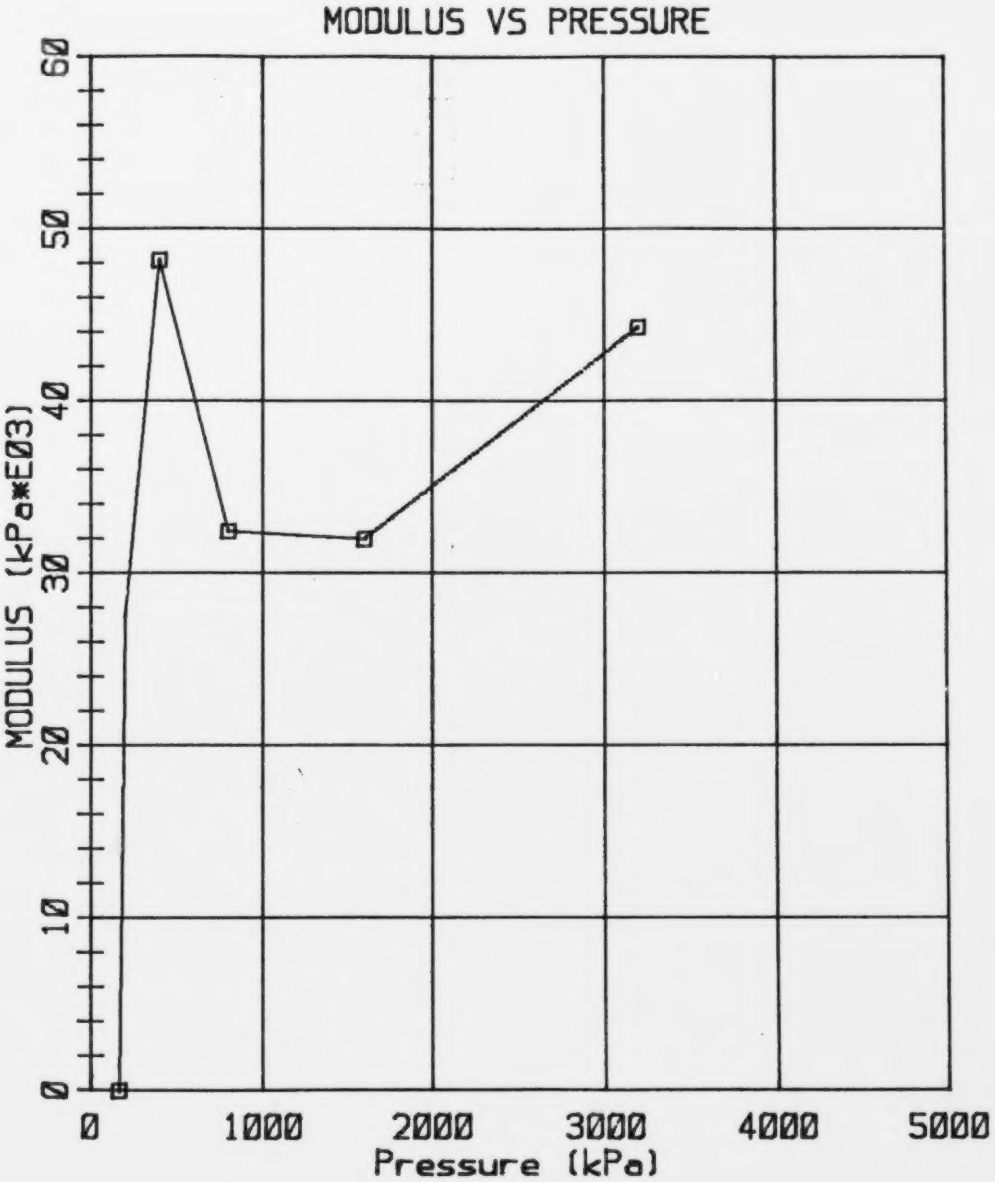
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 85-58 DEPTH: 4.2 m

PROJECT NO: S85-1774



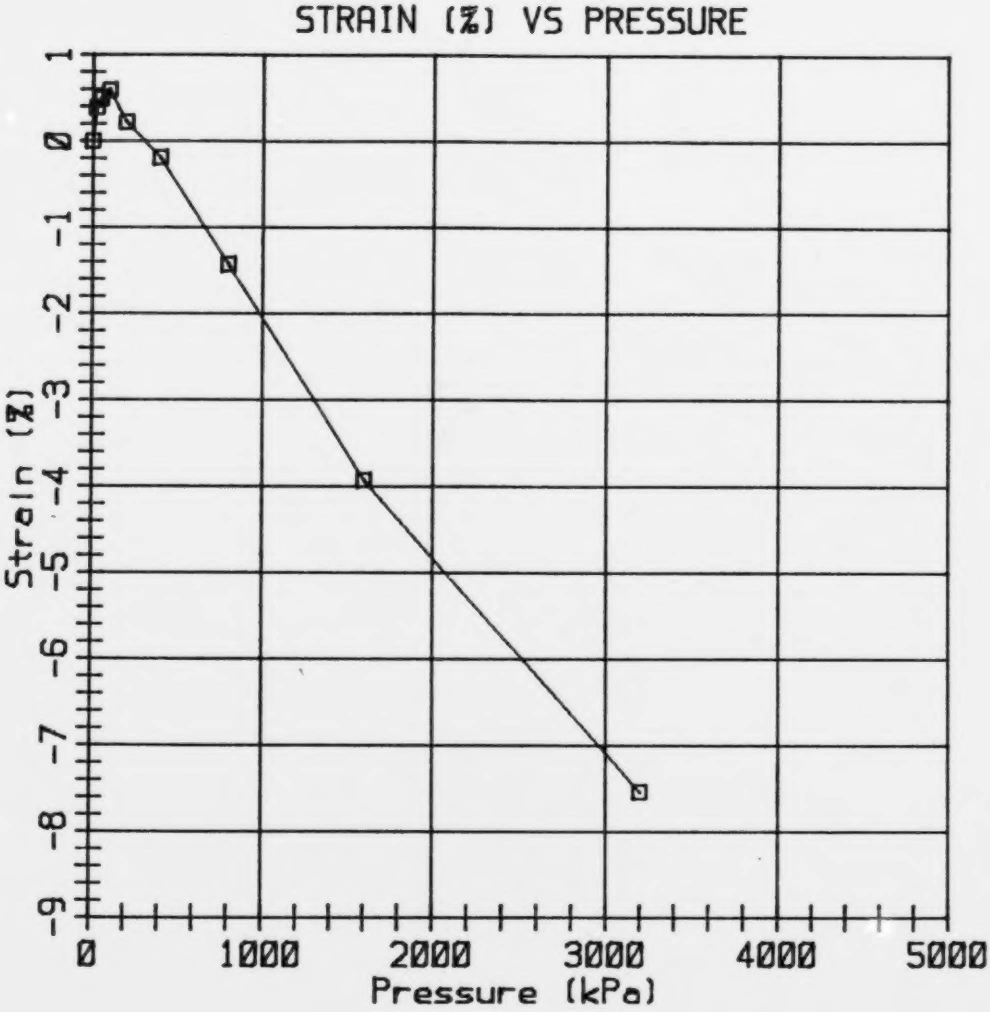
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 05-50 DEPTH: 42 m

PROJECT NO: S85-1774



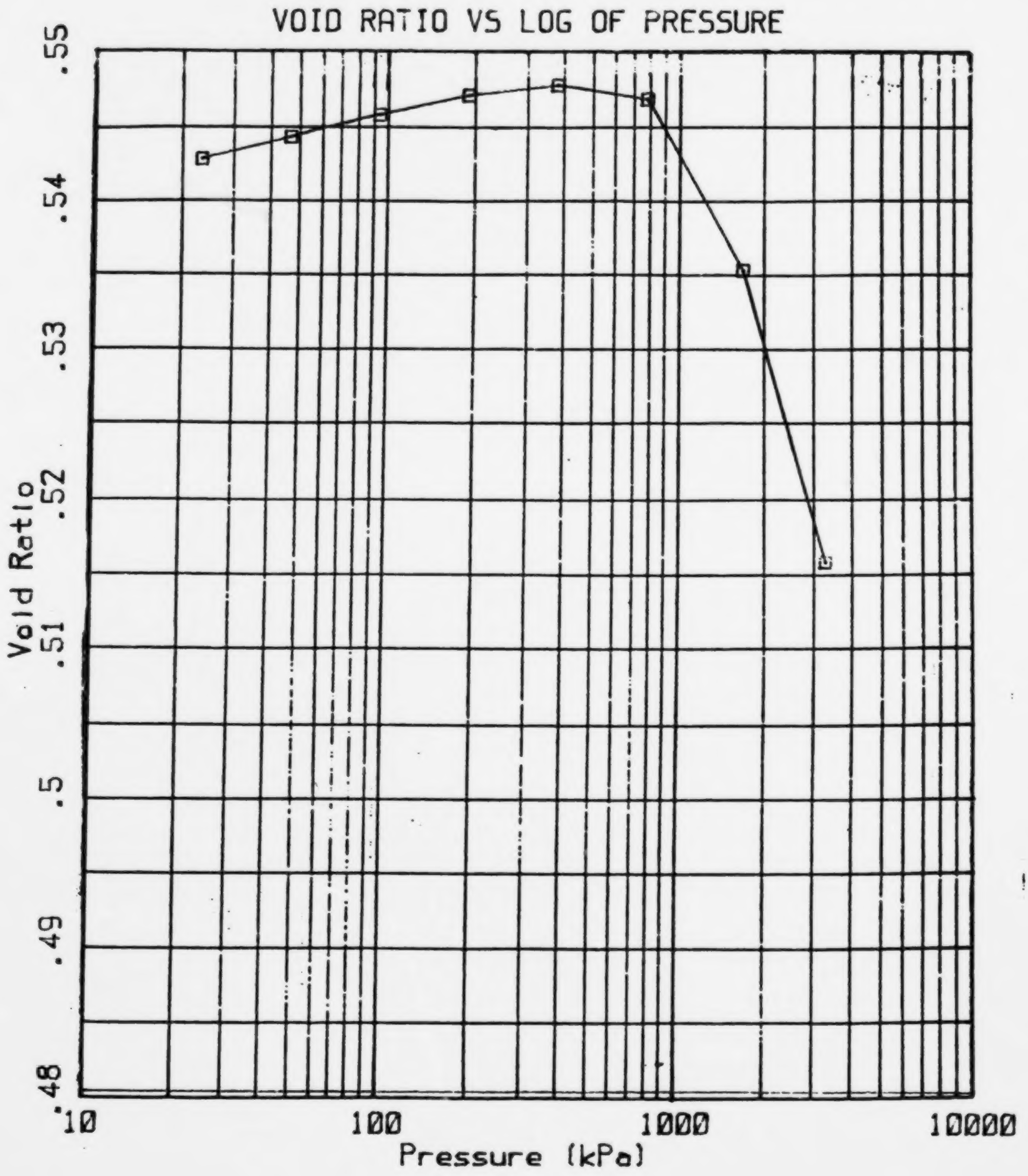
BGT Geotechnical Consultants Ltd.
BGT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 05-50 DEPTH: 42 m

PROJECT NO: S85-1774



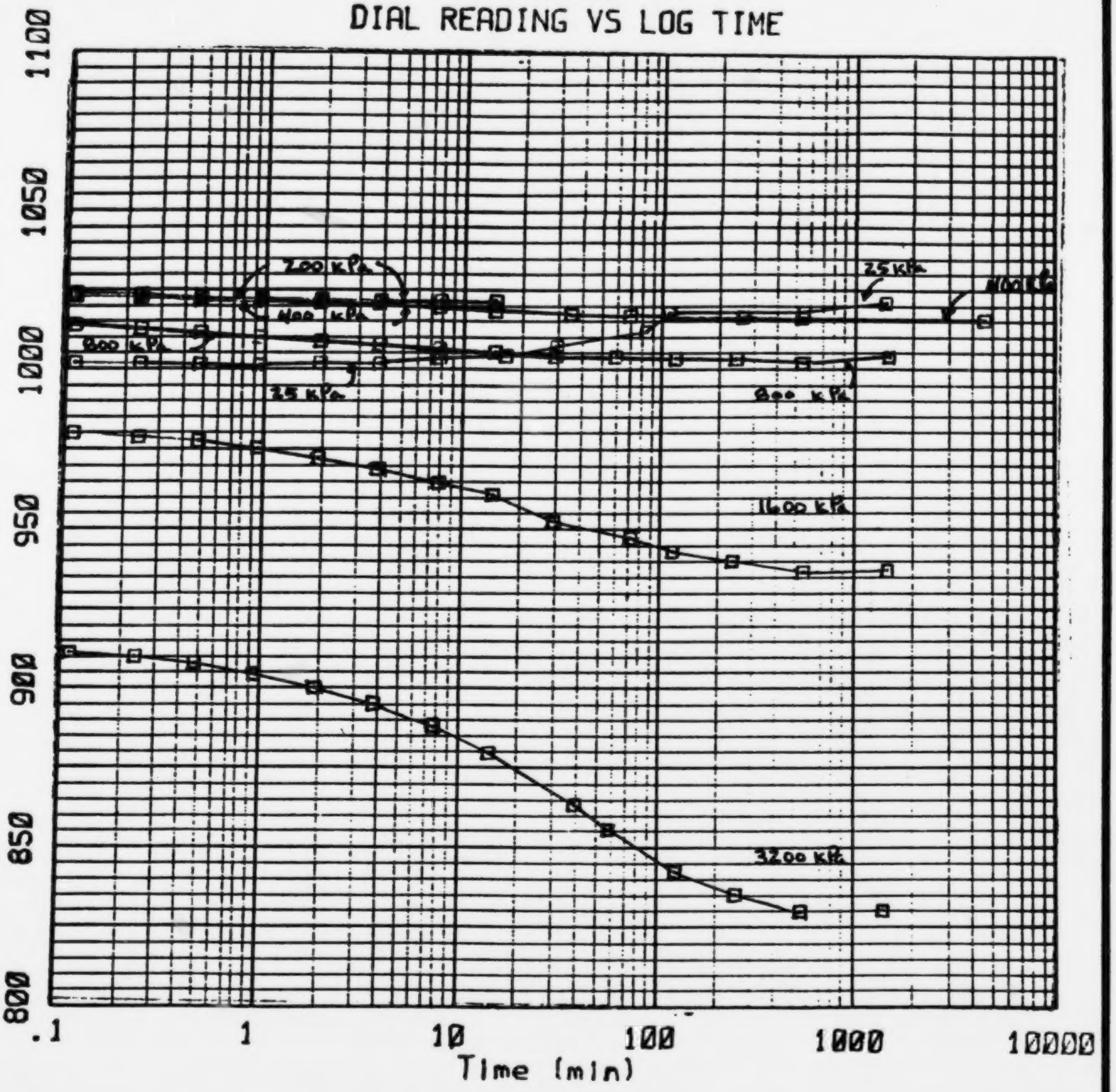
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 43.7 – 43.9m

PROJECT NO: S85-1774



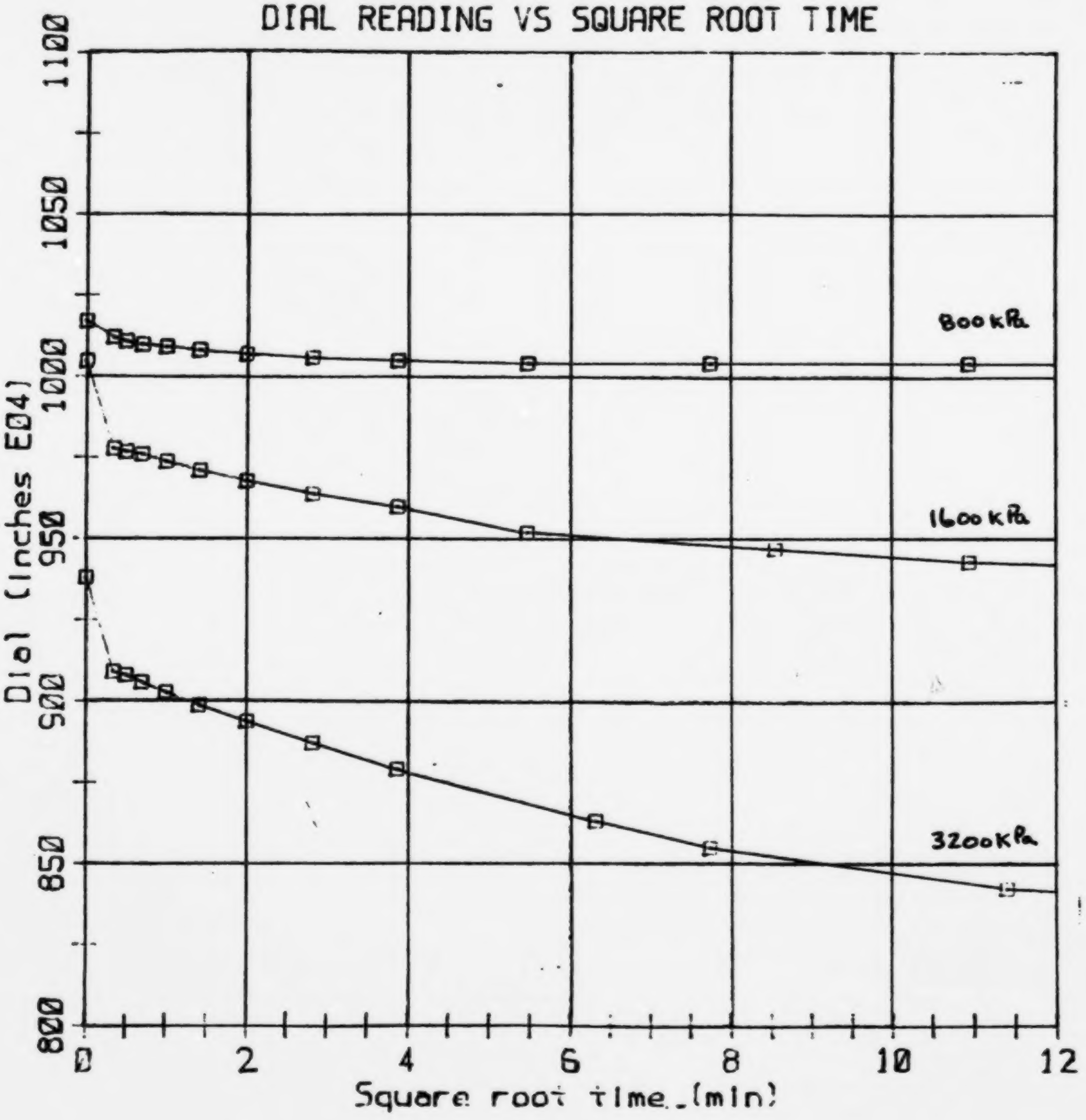
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 43.7–43.9m

PROJECT NO: S85-1774

 DIAL READING VS SQUARE ROOT TIME

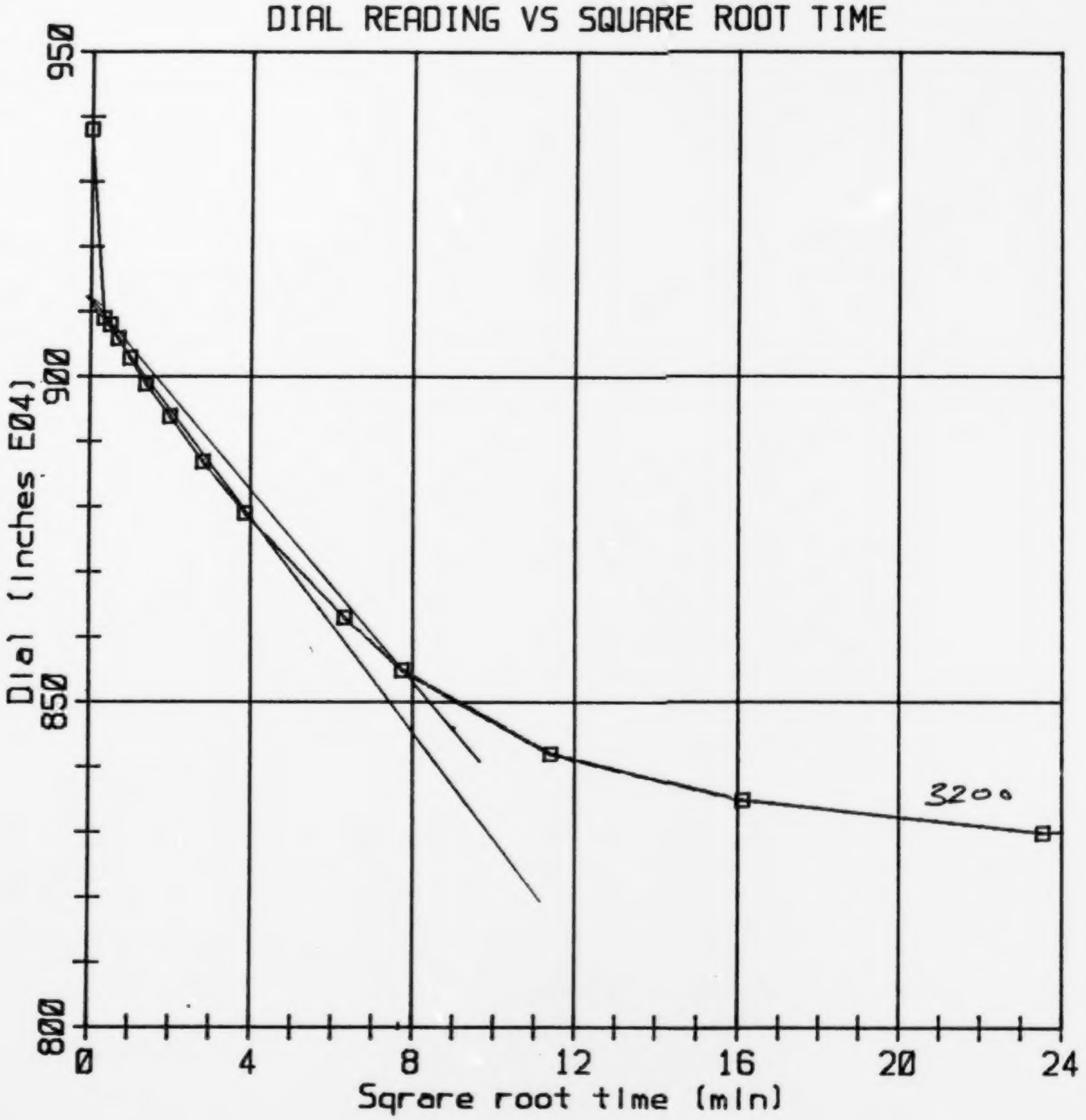
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 43.7–43.9m

PROJECT NO: S85-1774

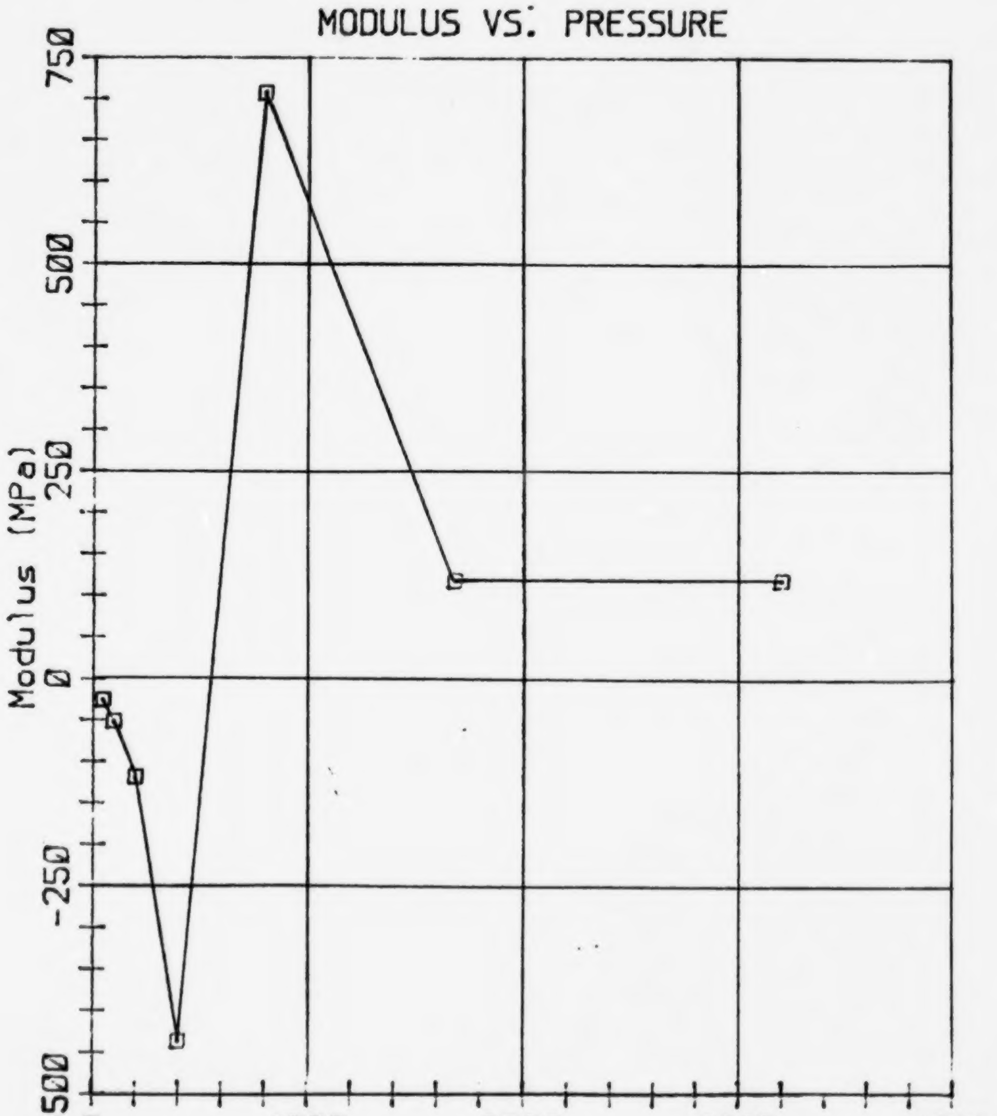


BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

CONSOLIDATION TEST

SAMPLE NO. ..... _ .....

DRAWING NO.



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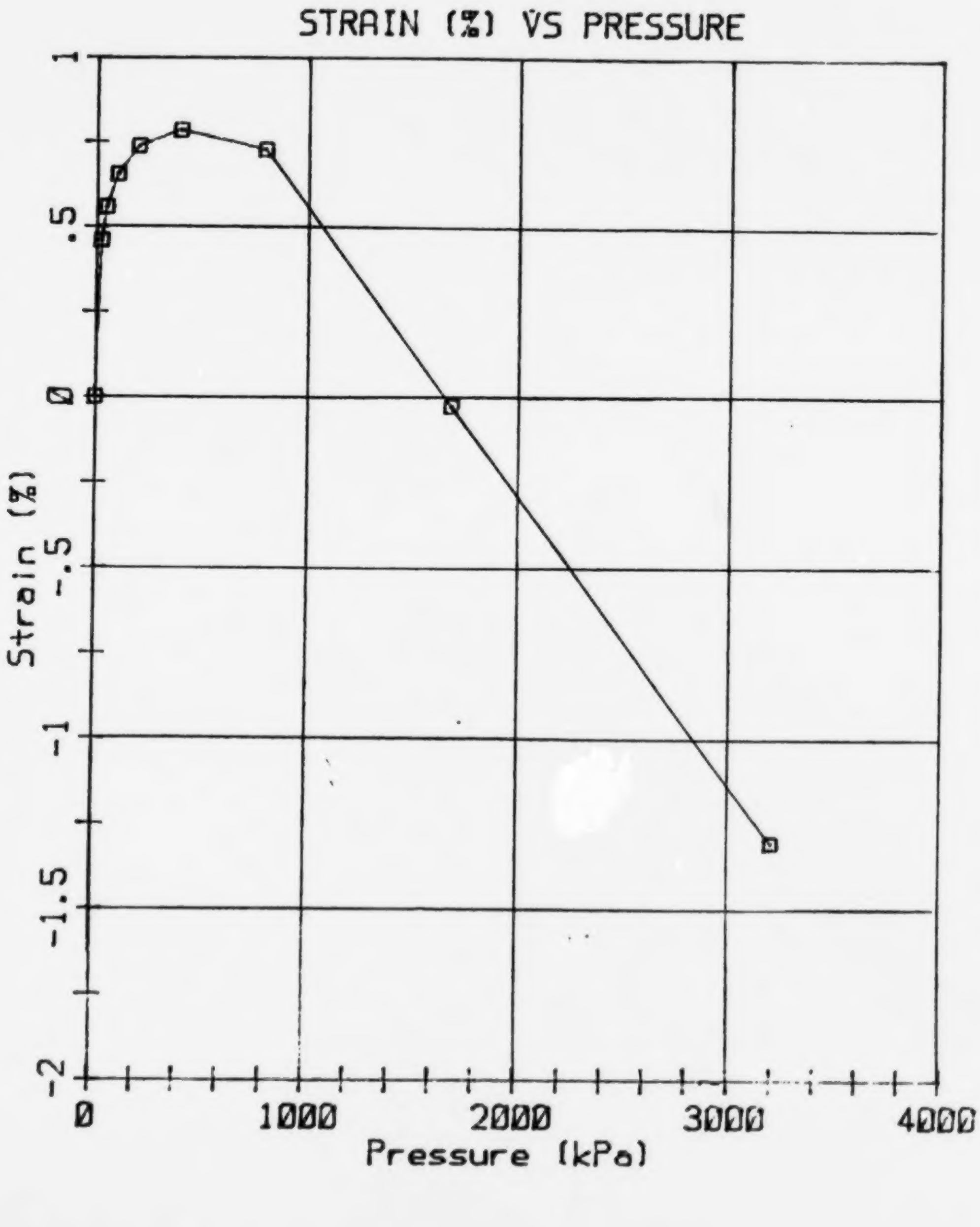
Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 43.7-43.9m

PROJECT NO: S85-1774



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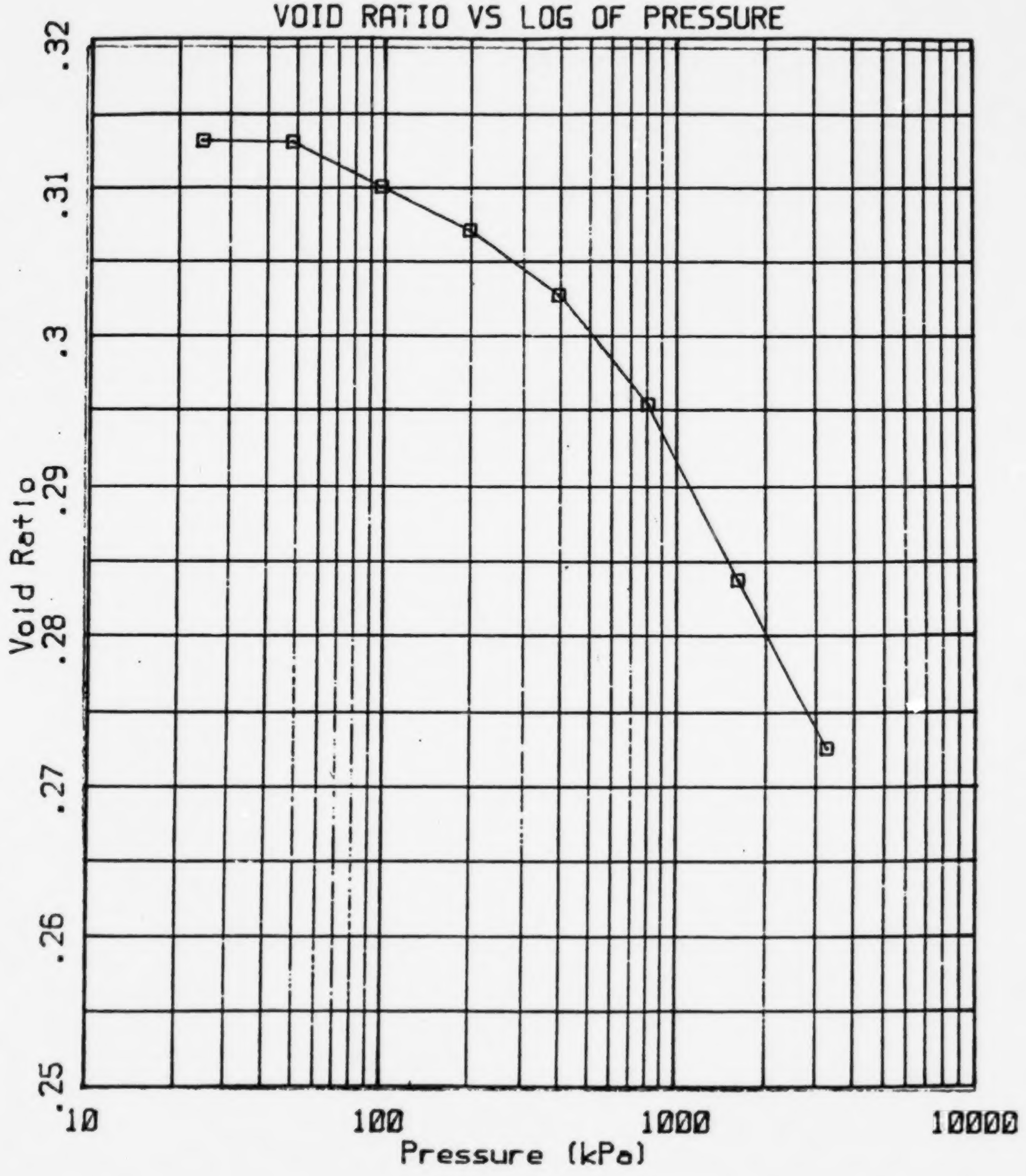
Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 58 DEPTH: 43.7-43.9m

PROJECT NO: S85-1774



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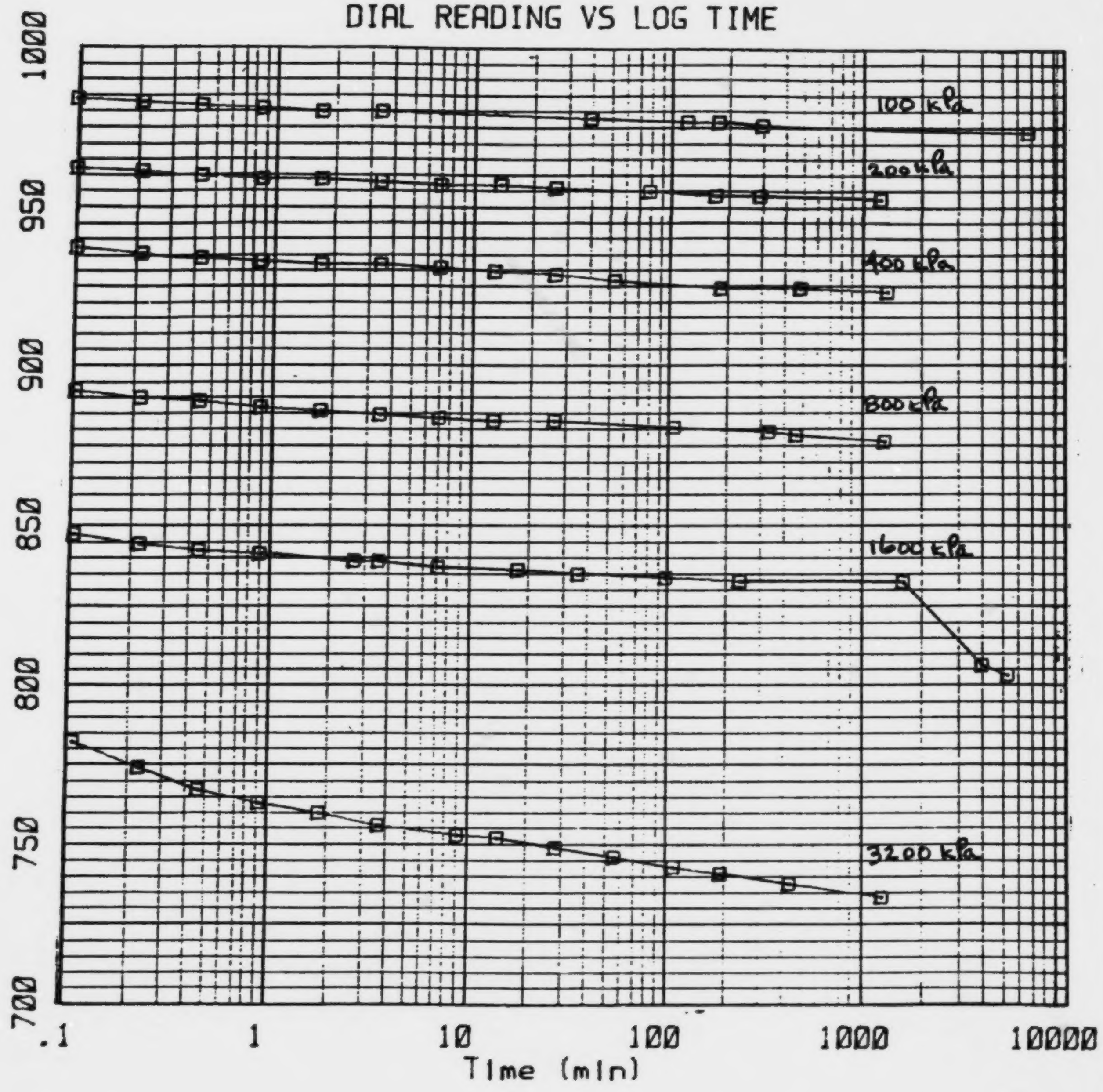
Tails Pile
Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 13.0M

PROJECT NO: S85-1774



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BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS ROCANVILLE

CONSOLIDATION TEST

TEST HOLE NO: 68 DEPTH: 43.0m

PROJECT NO: S85-1774

4-9192

FOUNDATION PORE PRESSURE
UNDER POTASH WASTE PILES

APPENDIX [illegible] 4-8 IIC

VOLUME II

(PCS MINING, LANIGAN DIVISION)

REPORT ON INSTALLATION OF
TAILS PILE INSTRUMENTATION FOR
POTASH CORPORATION OF SASKATCHEWAN
MINING LIMITED - LANIGAN DIVISION
PHASE II EXPANSION

CONTRACT NO. LC-7046

VOLUME II - APPENDICES 4 - 8 INC.

Prepared For:

POTASH CORPORATION OF SASKATCHEWAN
MINING LIMITED - LANIGAN DIVISION
SUITE 500, 122 - 1ST AVENUE SOUTH
SASKATOON, SASKATCHEWAN
S7K 7G3

Prepared By:

BBT GEOTECHNICAL CONSULTANTS LTD.
221 JESSOP AVENUE
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S7N 1Y3

AUG 15 1986
MICROMEDIA

162 pp

BBT PROJECT NO. S84-1746

NOVEMBER 7, 1985

BBT Geotechnical Consultants Ltd.

TABLE OF CONTENTS

Page No.

1.0 PROJECT DETAILS

- 1.1 General Description of the Work — 1
- 1.2 Development and Scheduling of the Work — 1
- 1.3 Instrumentation Details — 3
- 1.4 Site Description — 4

2.0 FIELDWORK

- 2.1 Site Preparation — 5
- 2.2 Drilling, Logging and Sampling — 5
- 2.3 Installation of Instrumentation
  - 2.3.1 Pneumatic Pore Pressure Indicators (Piezometers) — 6
  - 2.3.2 Settlement Sensors — 7
  - 2.3.3 Slope Inclinometer Casings — 10
  - 2.3.4 Permanent Bench Mark — 10
  - 2.3.5 Installation Difficulties — 10
- 2.4 Installation of Leads — 12
- 2.5 Readout Terminal and Pore Pressure Indicator Instrument — 13
- 2.6 Instrumentation Readings — 13
- 2.7 Survey Ties — 19

3.0 LABORATORY TESTING

- 3.1 General — 19
- 3.2 Subsurface Soil Profile — 20
- 3.3 Consolidation Testing — 24
- 3.4 Pore Pressure Response Tests — 24
- 3.5 Slurry Conductivity Tests — 26
- 3.6 Carbonate Analyses — 27

4.0 CLOSURE — 27

LIST OF TABLES

		Page No.
TABLE I	Schedule of Work Activities	1
TABLE II	Instrumentation Grid Locations and Elevations	3
TABLE III	Instrumentation Components	4
TABLE IV	Transducer Serial Nos. and Tubing Lengths	8
TABLE V	Summary of Piezometric Observations	13 - 16
TABLE VI	Settlement Sensor Observations	17
TABLE VII	Summary of Atterberg Limit Tests	20 - 21
TABLE VIII	Results of Confined Compression Tests on $\bar{B}$ Samples	24
TABLE IX	Soil Slurry Conductivity Results	25
TABLE X	Soil Carbonate Content	26

LIST OF APPENDICES

APPENDIX 1	Site Plans Pilot Hole Log
APPENDIX 2	Test Hole Logs and Details of Installations
APPENDIX 3	Consolidation Test Results
APPENDIX 4	Pore Pressure Response ($\bar{B}$) Test Results
APPENDIX 5	Grain Size Distribution Curves
APPENDIX 6	Manufacturer's Information
APPENDIX 7	Photographs
APPENDIX 8	Field Notes, Miscellaneous Laboratory Notes and Details

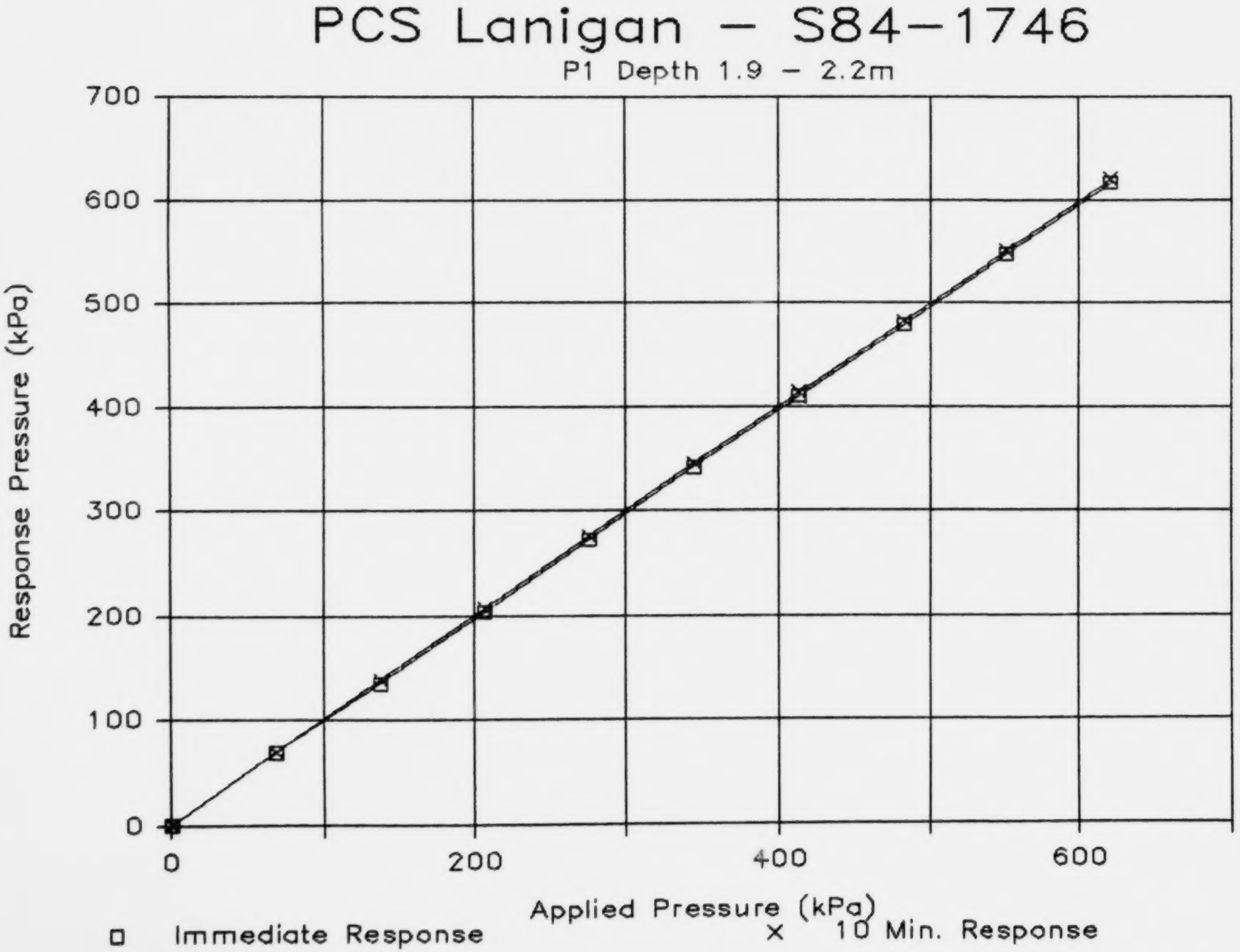
APPENDIX 4

Pore Pressure Response ($\bar{B}$) Test Results

APPENDIX 4

Pore Pressure Response ($\bar{B}$) Test Results

Installation	Sample Depth (m)	
P1	1.9 - 2.2	
~~P1~~ P2	3.5 - 3.7	Revision dated Dec 31/85
P4	7.3 - 7.5	
P5	11.1 - 11.3	
P6	14.5 - 14.6	
P7	19.1 - 19.2	
P8	27.7 - 27.9	
P9	32.0 - 32.3	
P10	44.3 - 44.5	
P11	62.6 - 62.7	
P12	79.8 - 80.0	
P12 Immediate Response	80.3 - 80.5	
P12 10 Minute Response	80.3 - 80.5	
P13	90.8 - 91.1	
P15	2.4 - 2.5	
P16	3.6 - 4.0	
P17	10.1 - 10.5	
P18	12.6 - 13.0	
P19	25.3 - 25.5	
P20	47.7 - 48.0	
P21	61.9 - 62.0	
P21 Immediate Response	63.3 - 63.4	
P21 10 Minute Response	63.3 - 63.4	

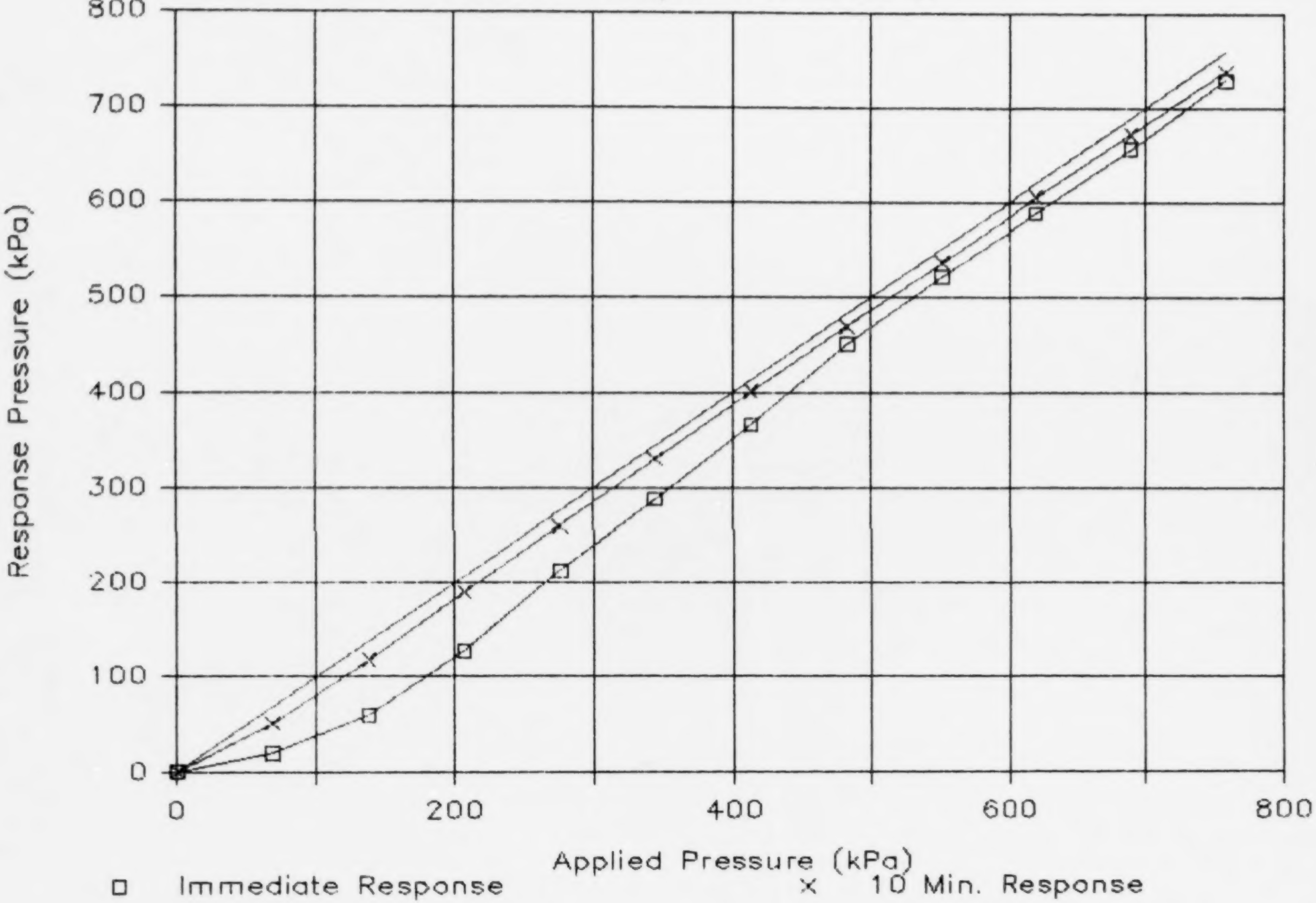


PCS Lanigan — S84-1746

P1 Depth 1.9 - 2.2m

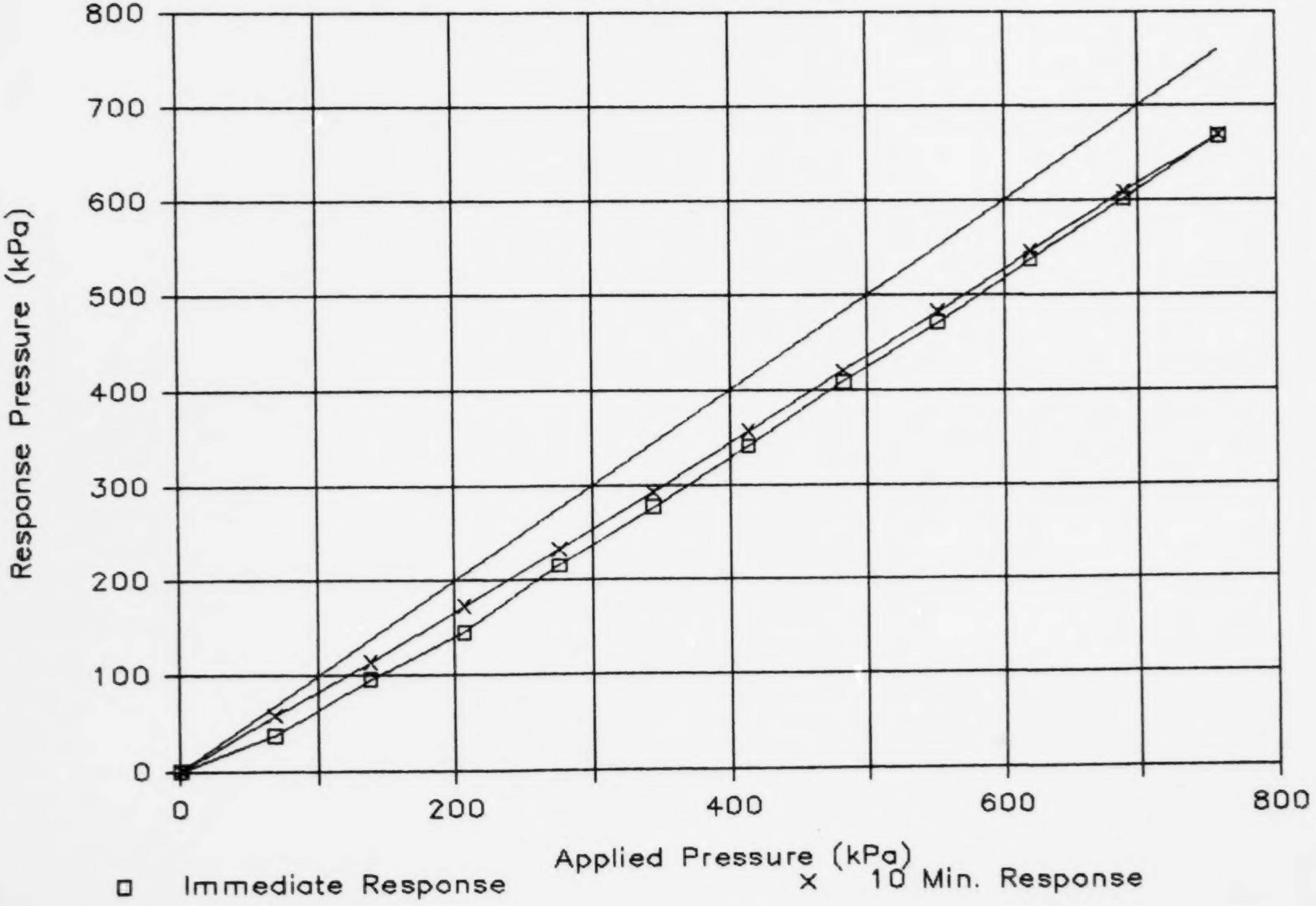
PCS Lanigan – S84–1746

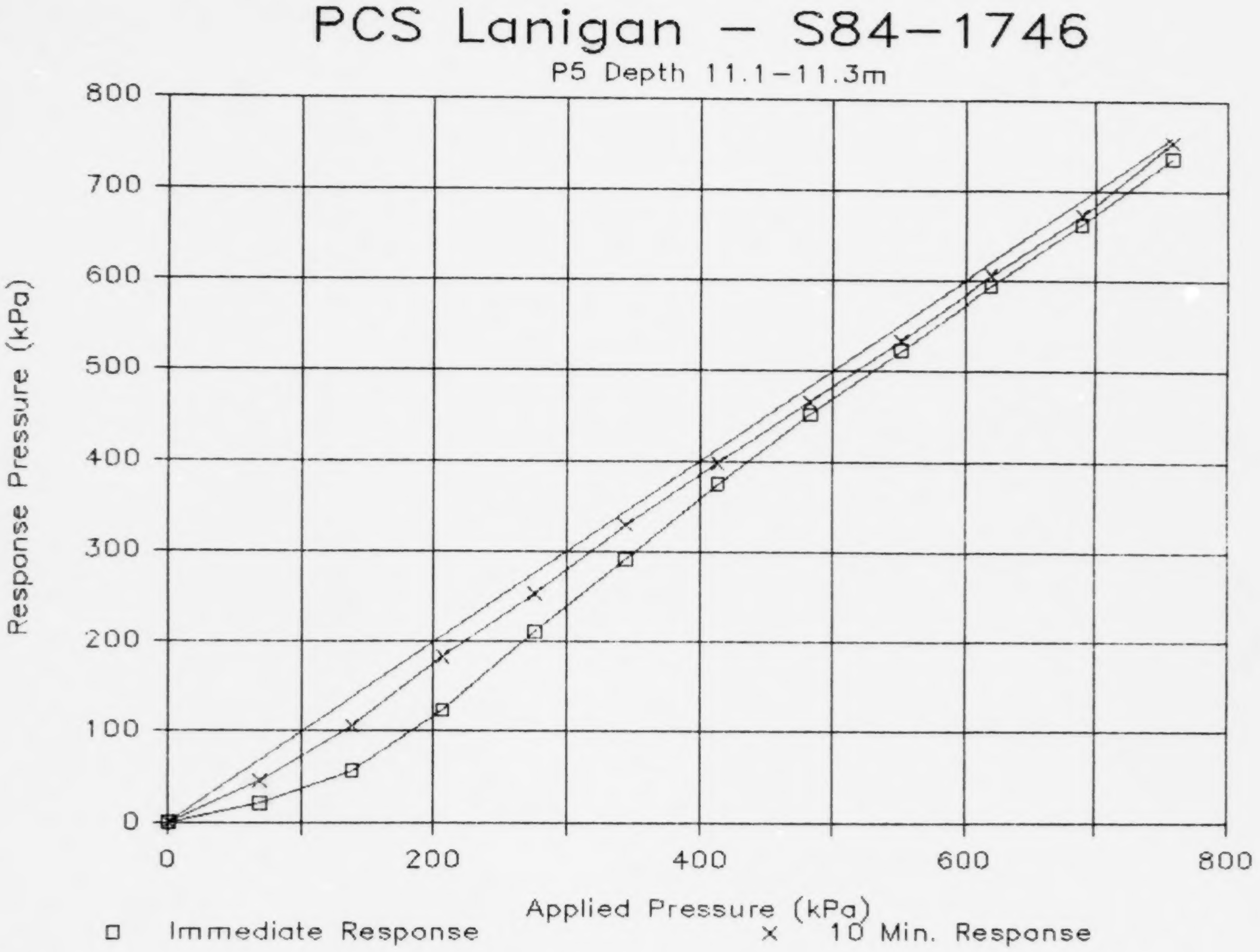
Revision dated Dec 27/85 → P2 ~~P1~~ Depth 3.51–3.66 m



PCS Lanigan – S84–1746

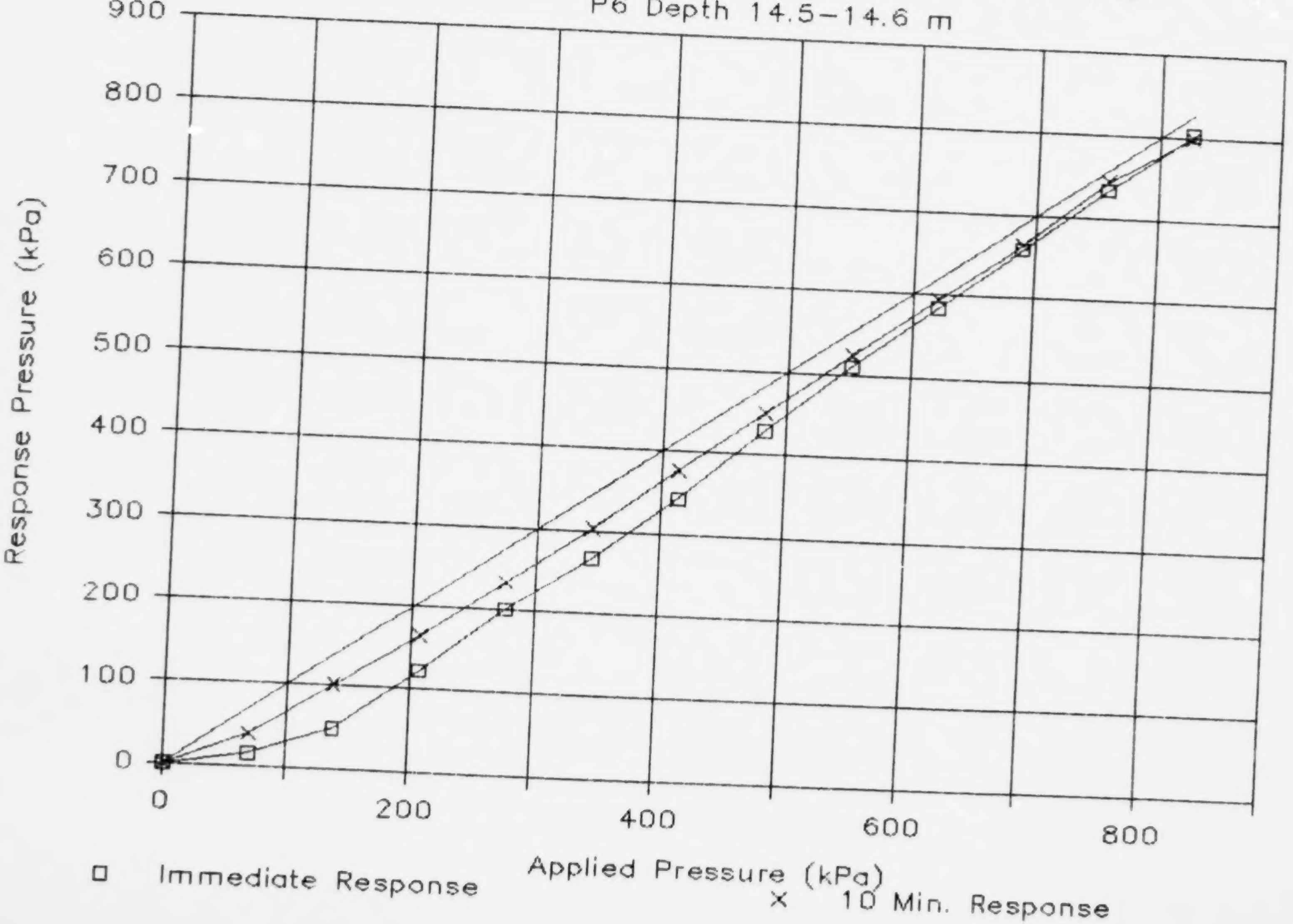
P4 7.3 – 7.5m




PCS Lanigan – S84–1746
P5 Depth 11.1–11.3m
Response Pressure (kPa)
800
700
600
500
400
300
200
100
0
0
200
400
600
800
Applied Pressure (kPa)
□ Immediate Response
× 10 Min. Response

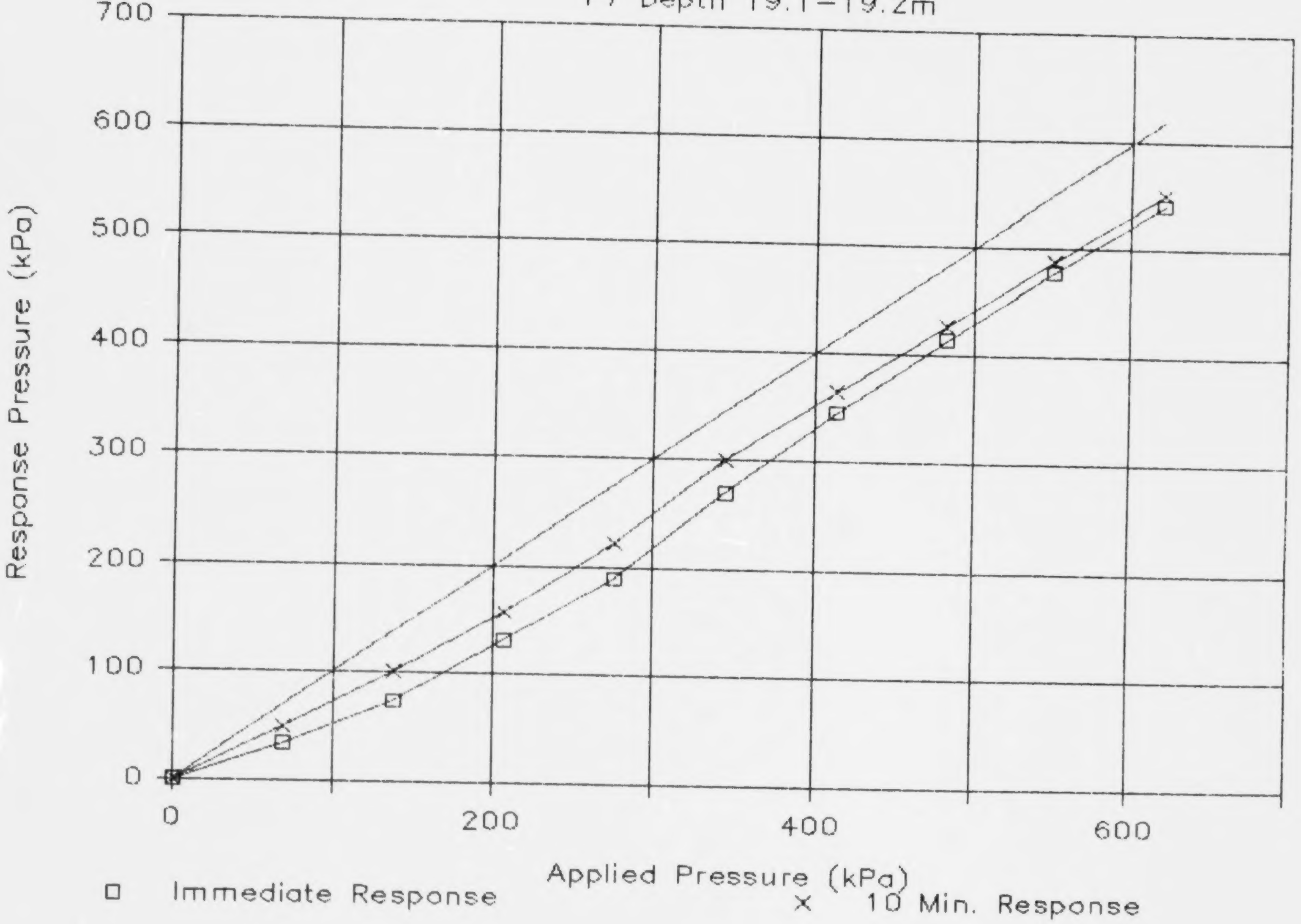
PCS Lanigan – S84–1746

P6 Depth 14.5–14.6 m



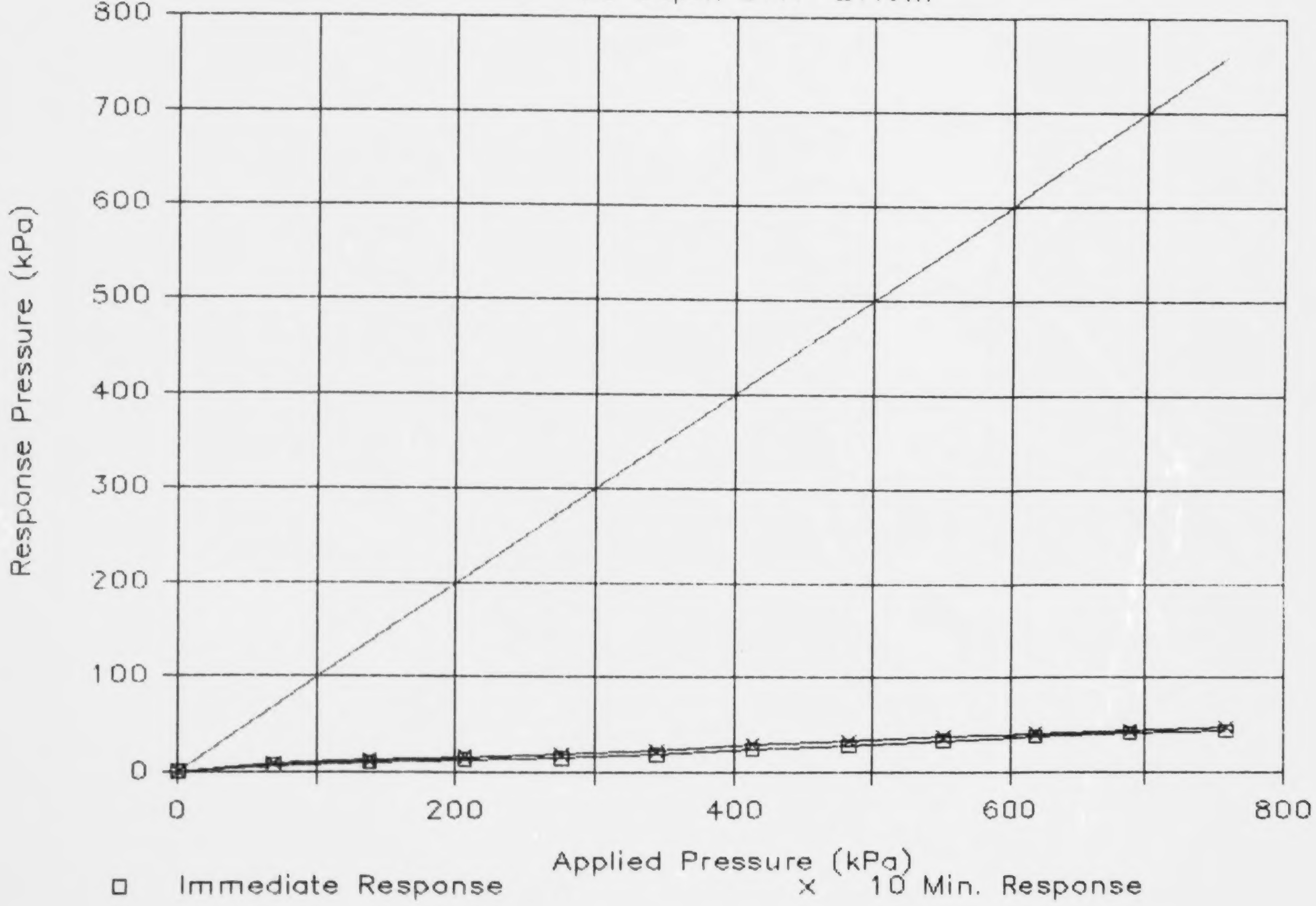
PCS Lanigan – S84–1746

P7 Depth 19.1–19.2m



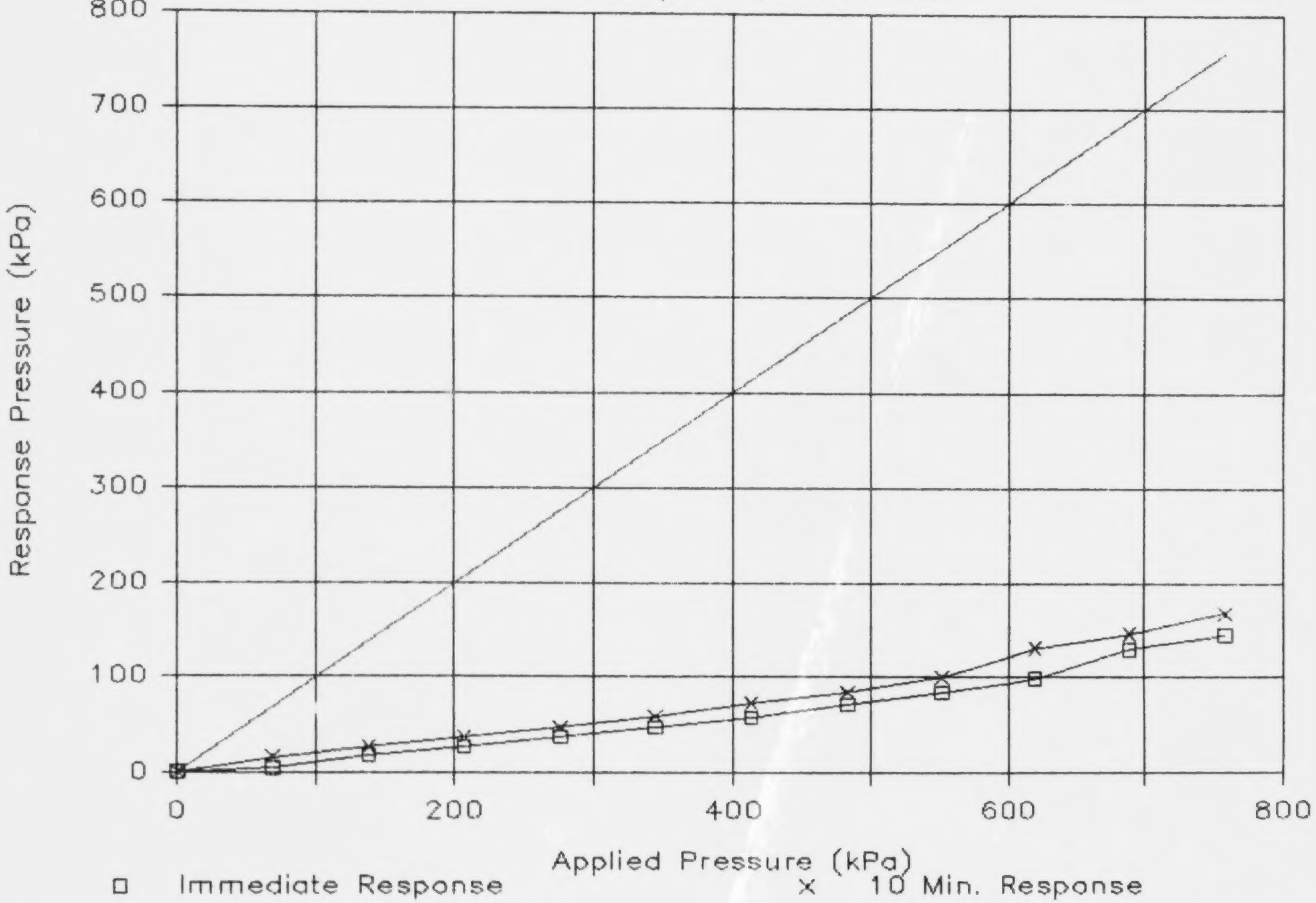
PCS Lanigan – S84–1746

P8 Depth 27.7–27.9m



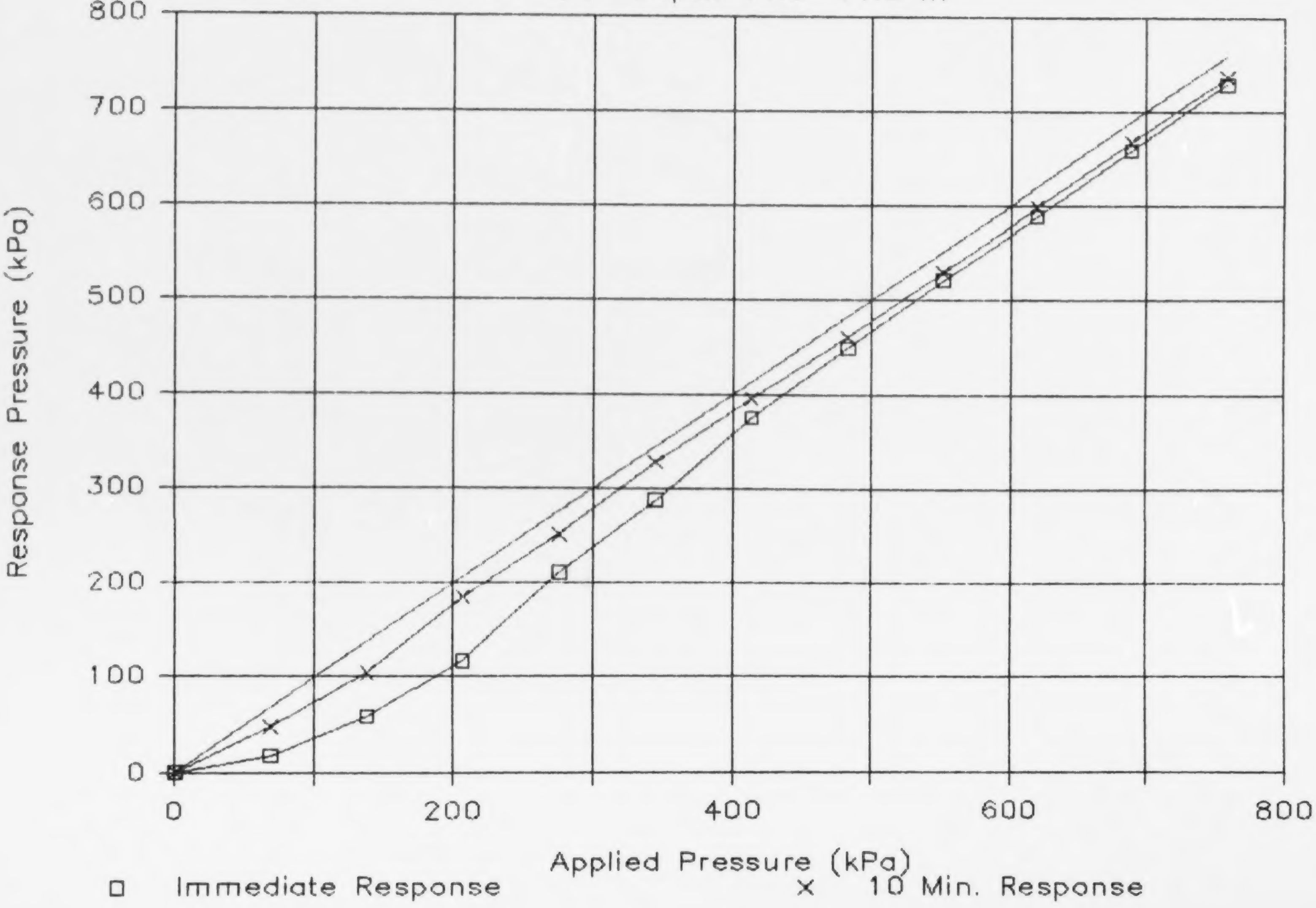
PCS Lanigan – S84–1746

P9 Depth 32.0–32.3 m



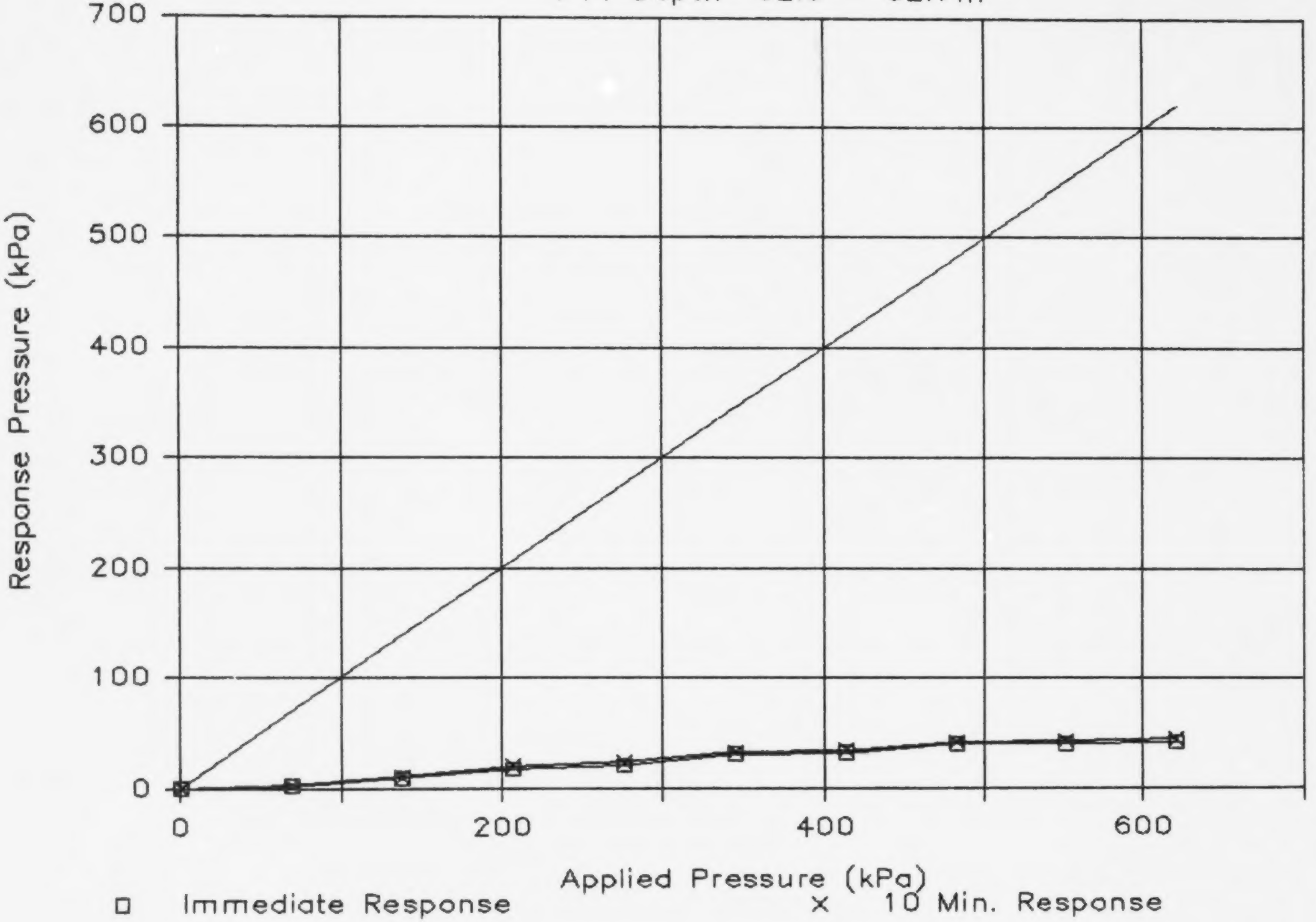
PCS Lanigan – S84–1746

P10 Depth 44.3–44.5 m



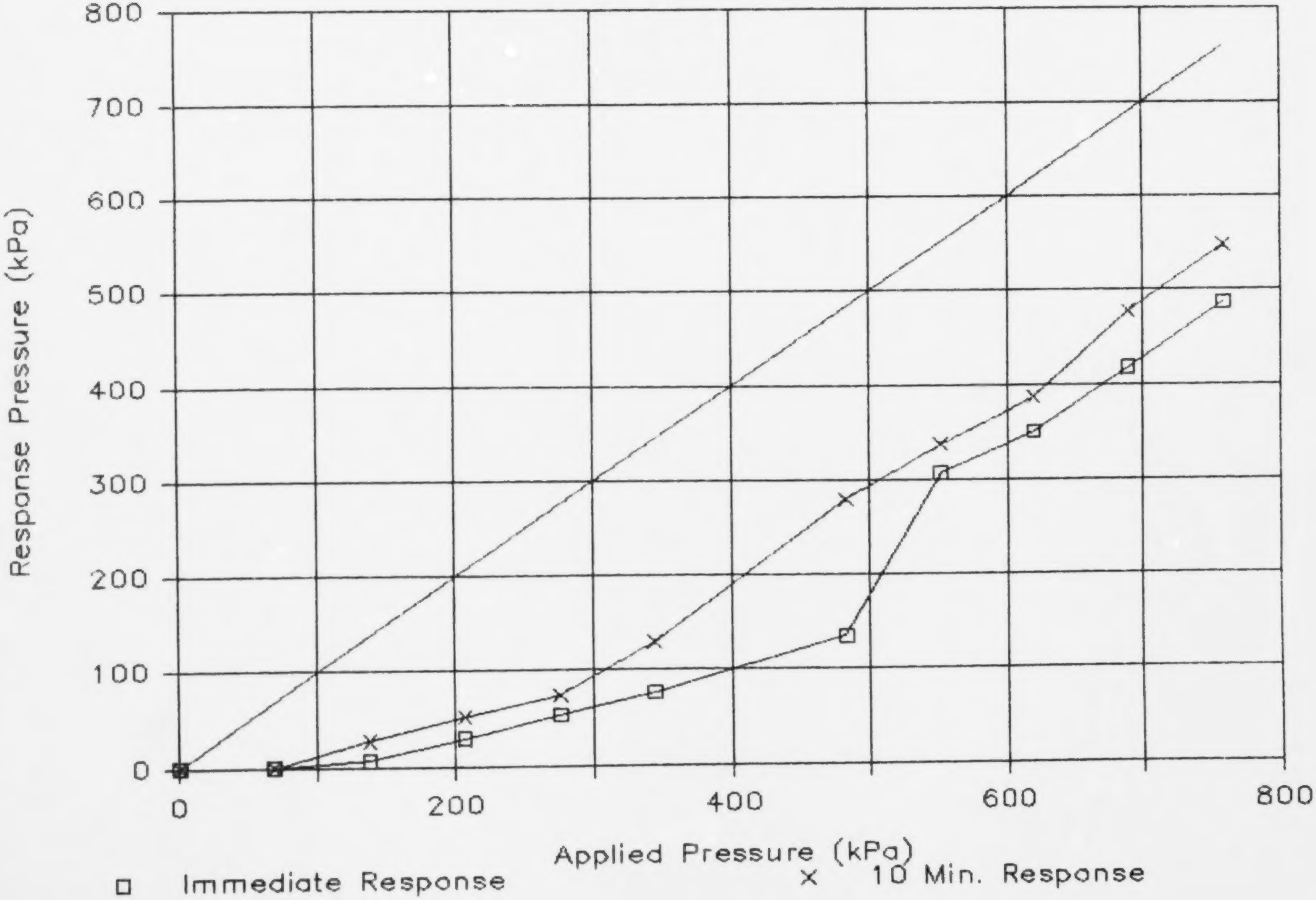
PCS Lanigan – S84–1746

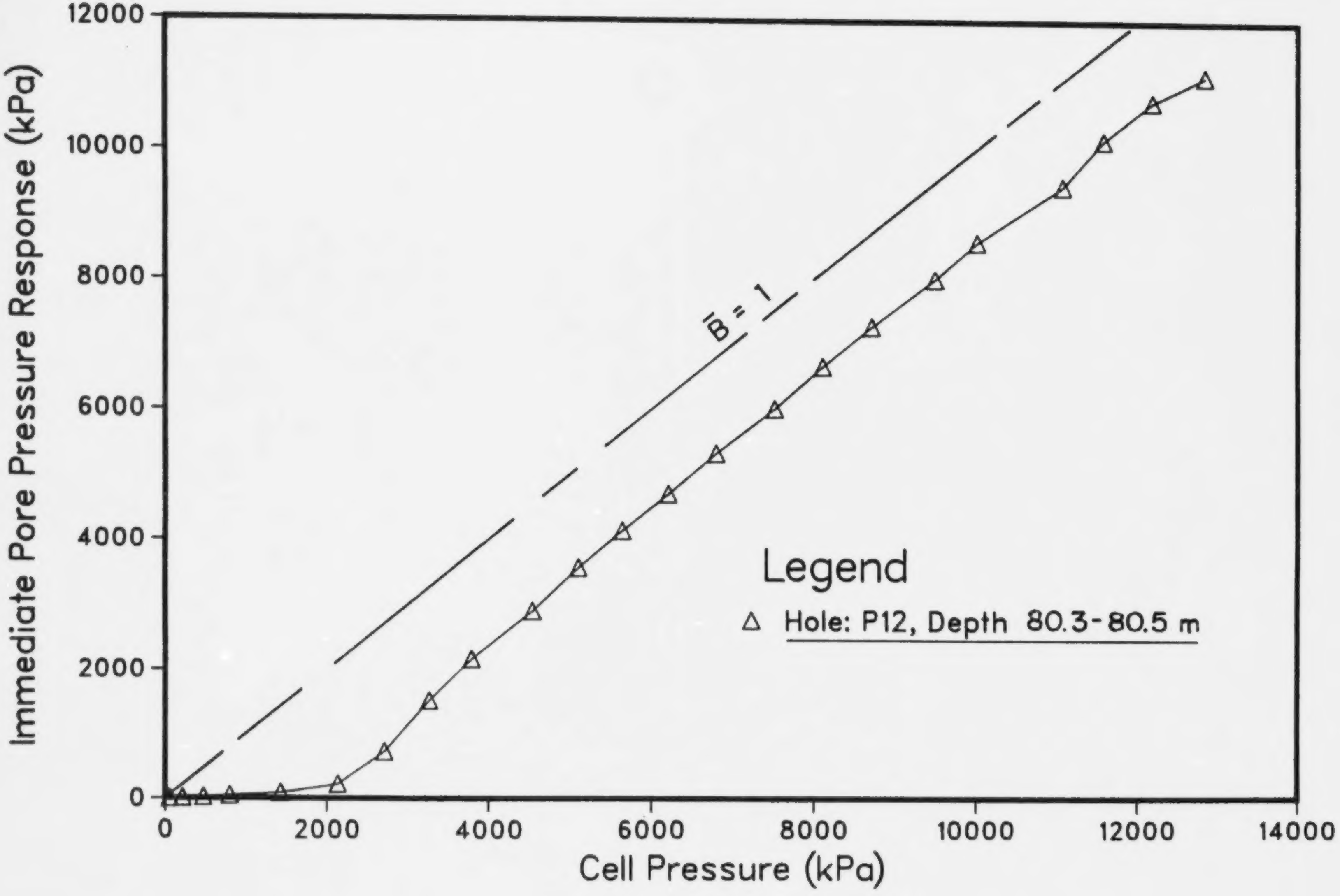
P11 Depth 62.6 – 62.7m



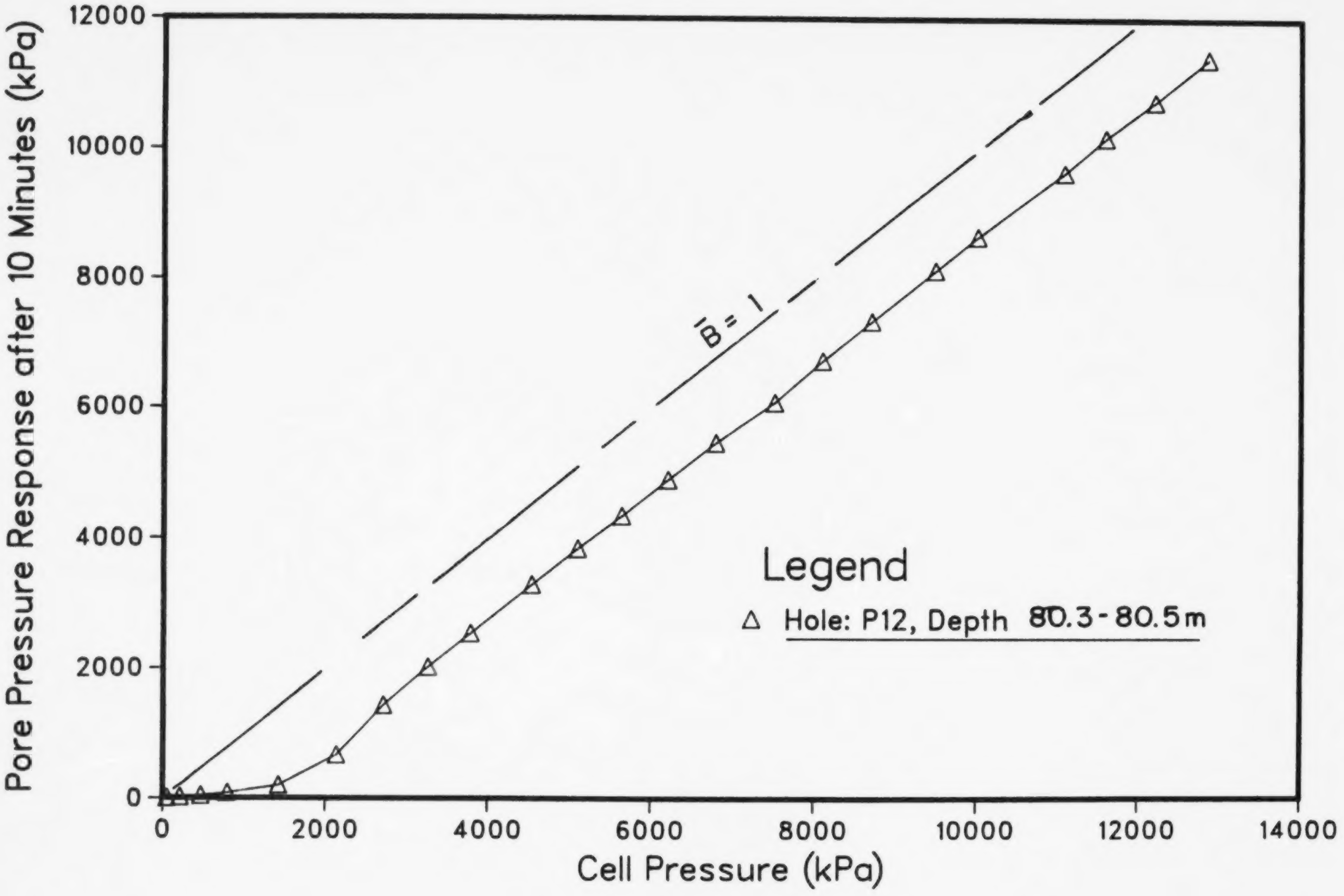
PCS Lanigan – S84–1746

P12 Depth 79.8–80.0 m





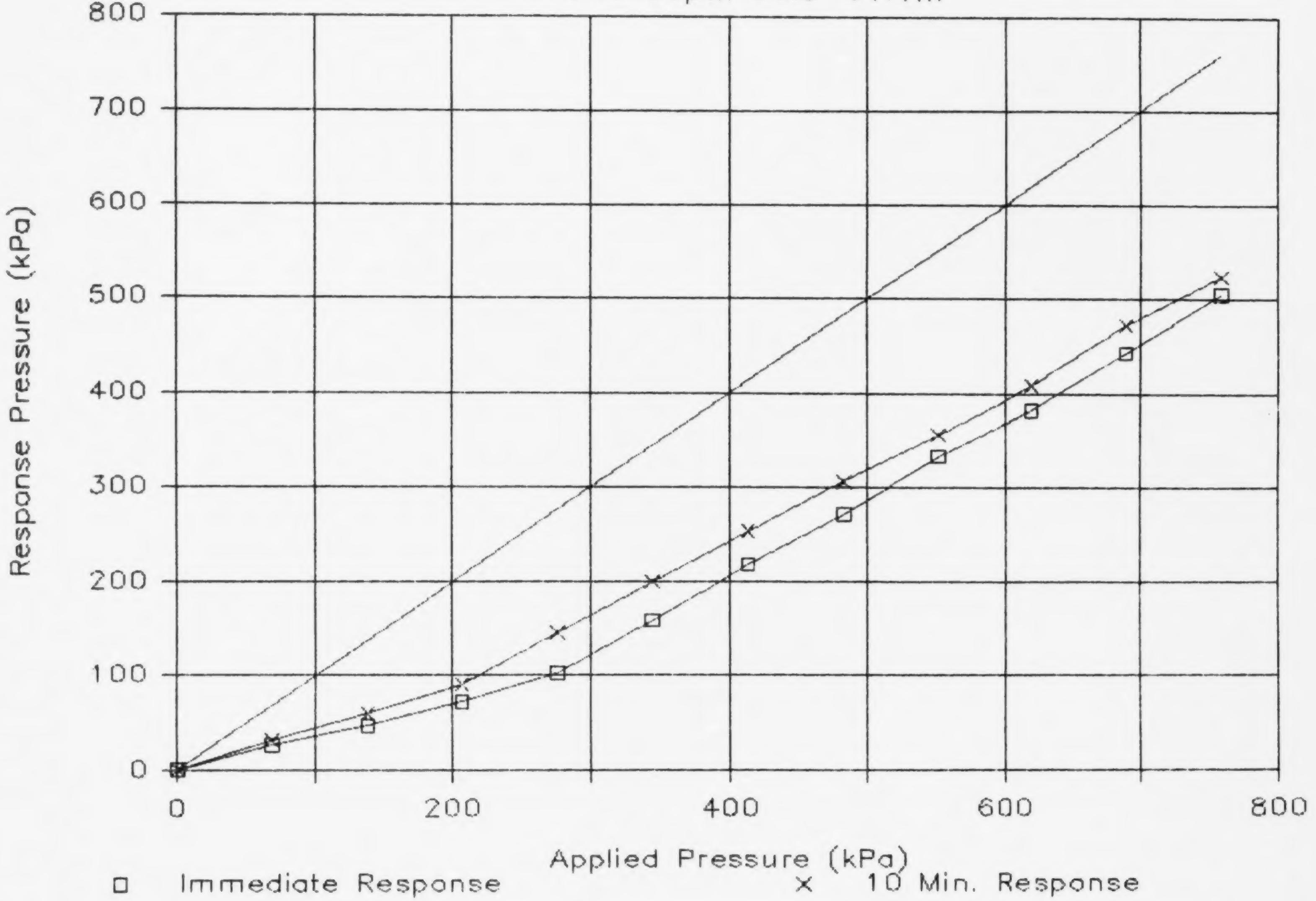
Immediate Pore Pressure Response



Pore Pressure Response after 10 Minuites

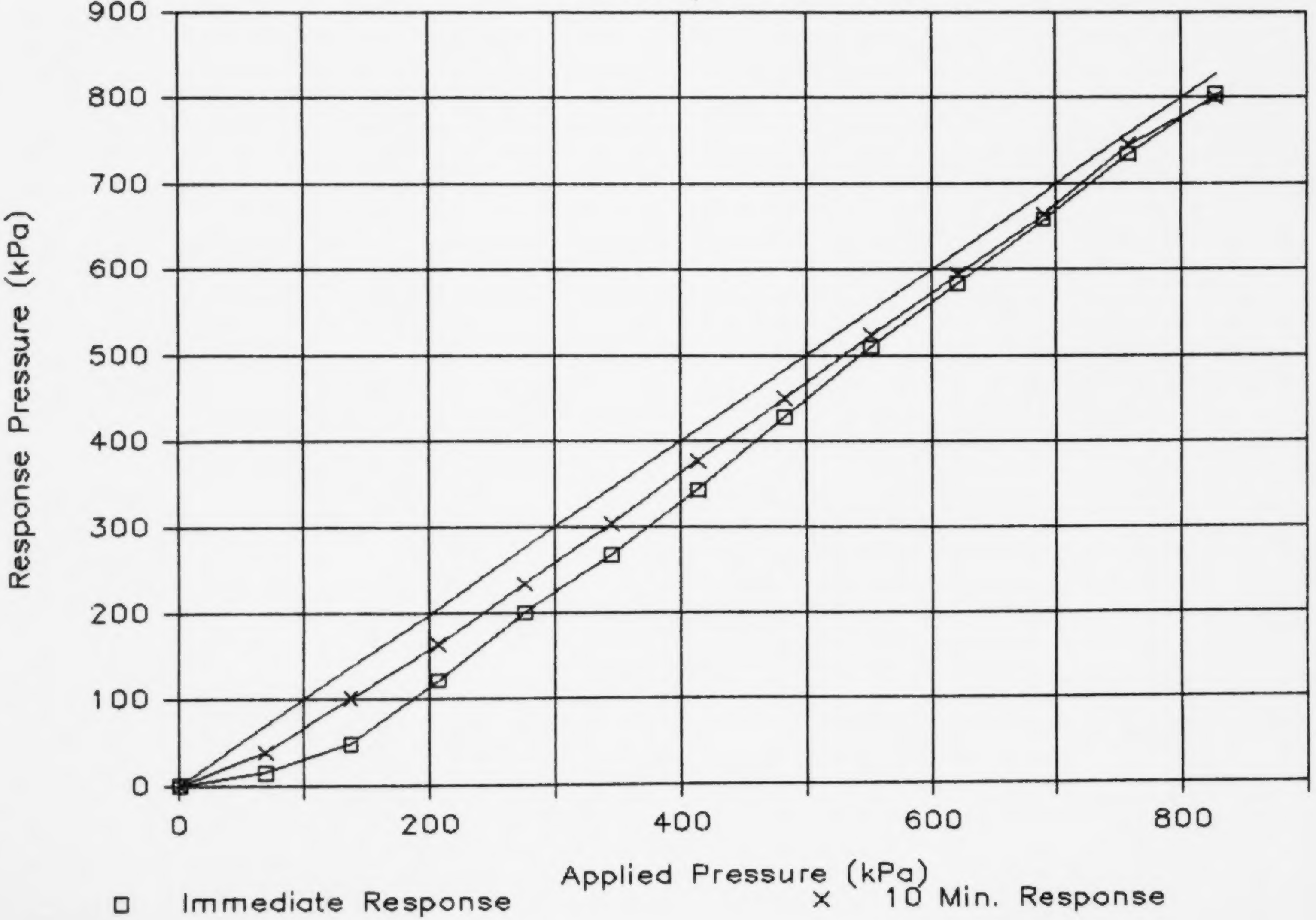
PCS Lanigan – S84–1746

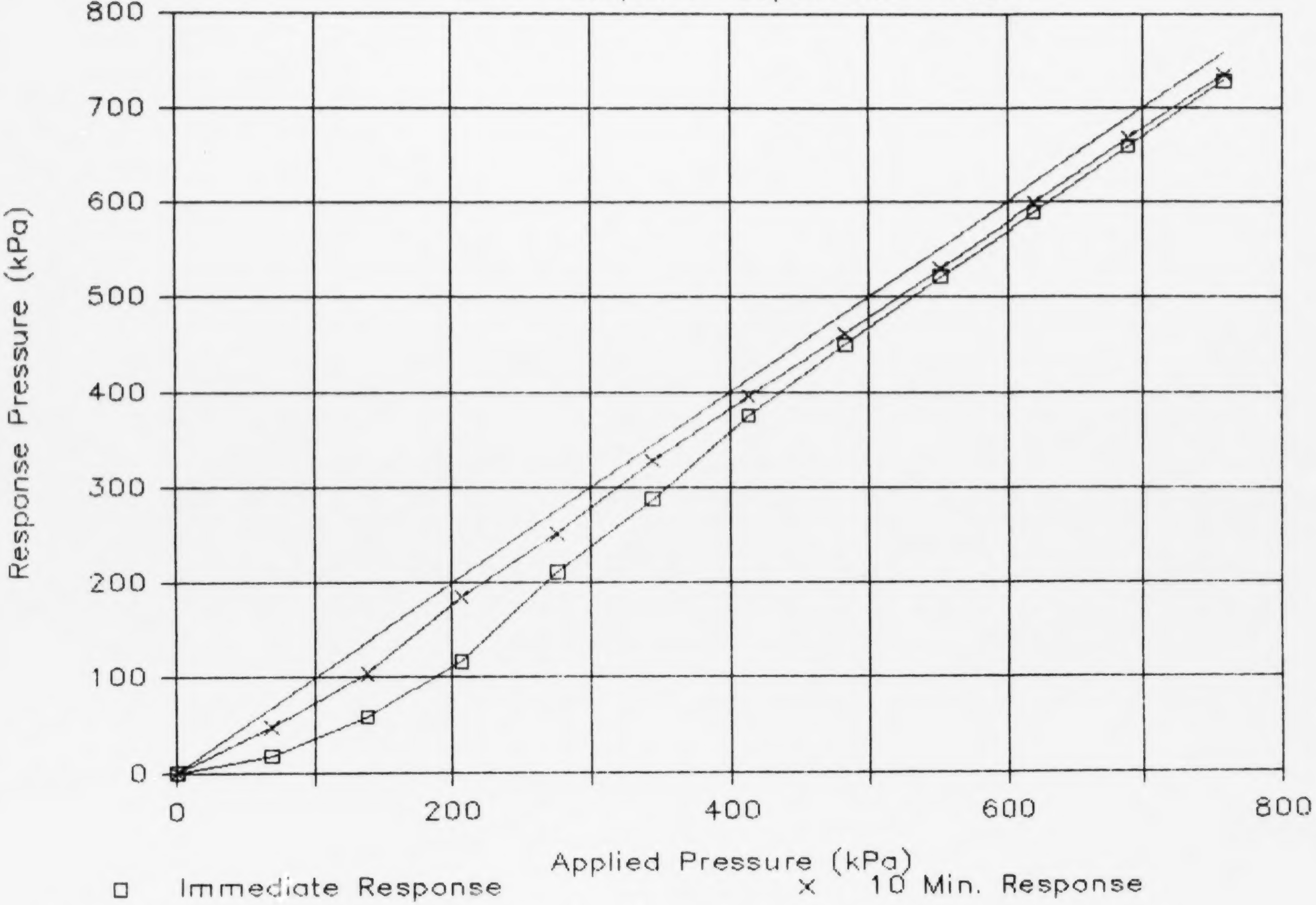
P13 Depth 90.8–91.1m



PCS Lanigan – S84–1746

P15 Depth 2.4 – 2.5 m



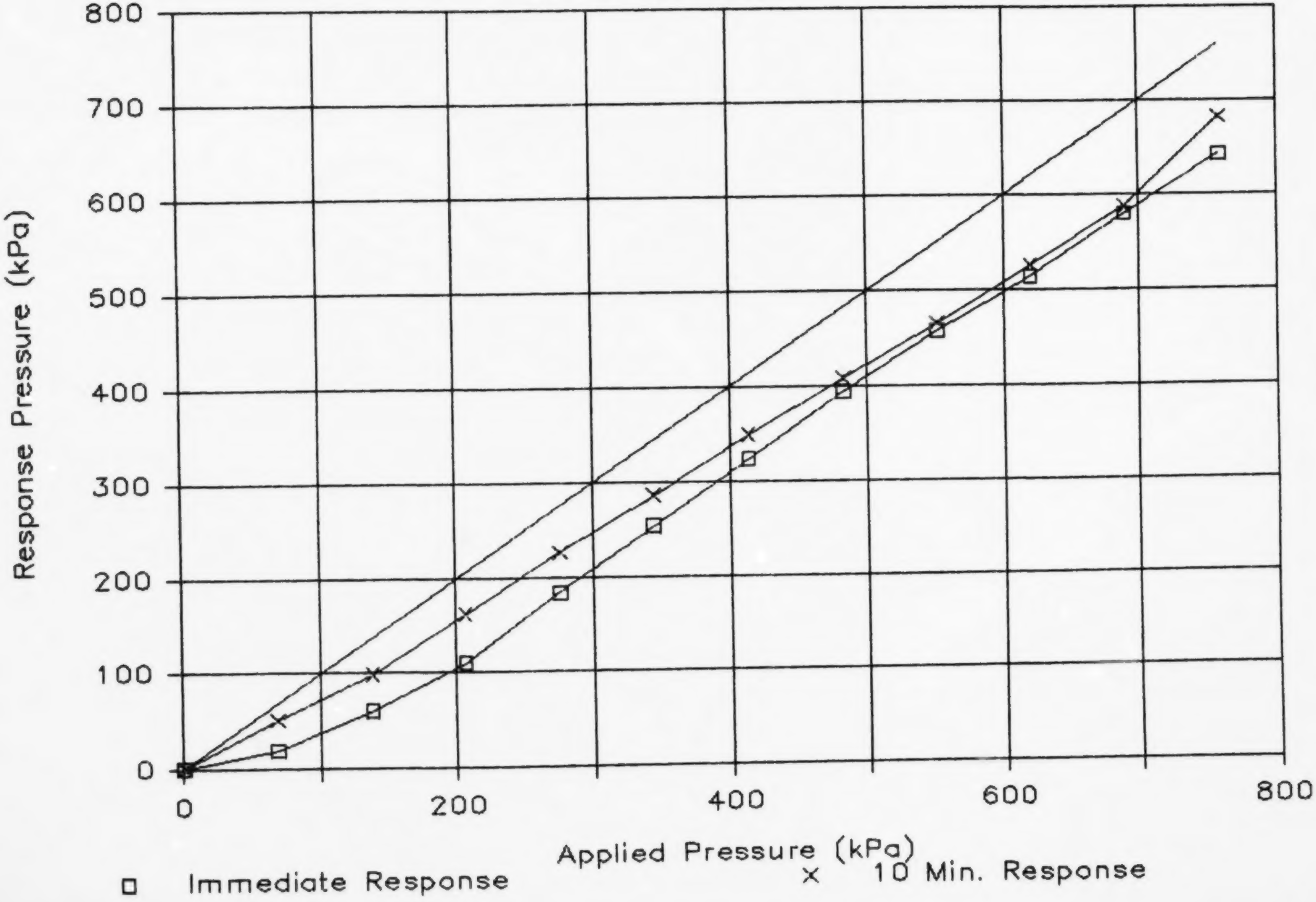


PCS Lanigan – S84–1746

P16 Sample 3 Depth 3.63–4.02m

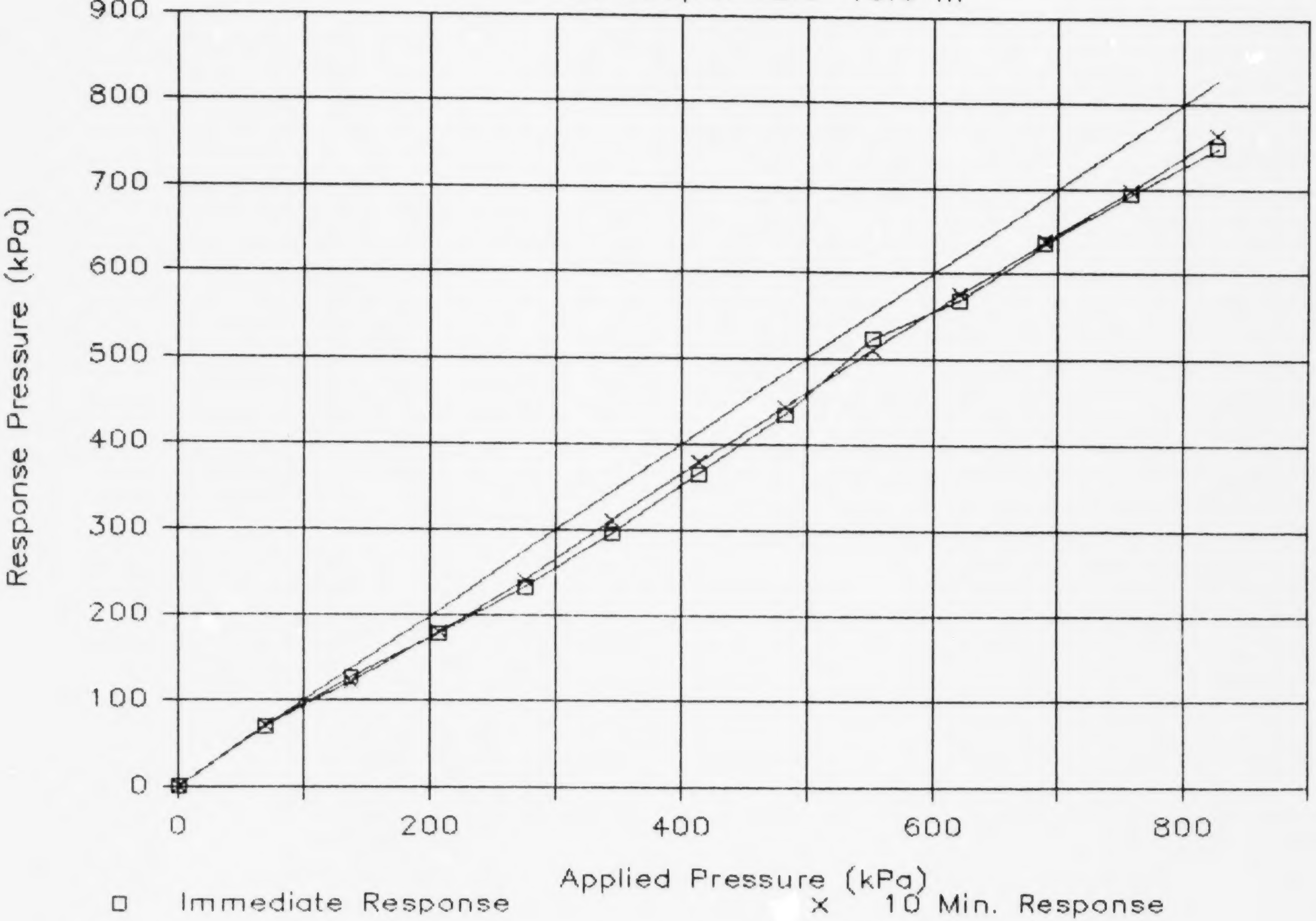
PCS Lanigan – S84–1746

P17 Depth 10.1 – 10.5m



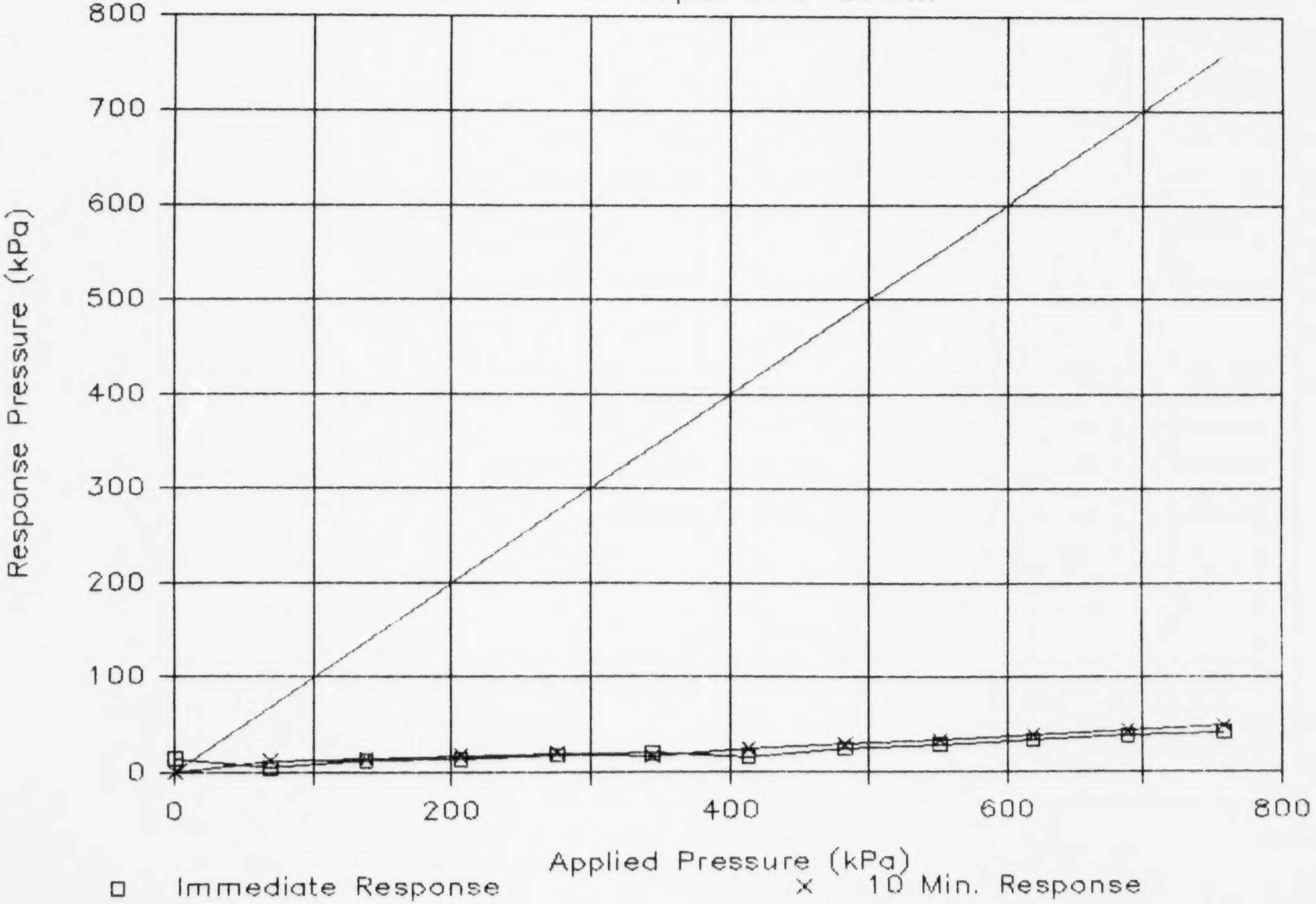
PCS Lanigan – S84–1746

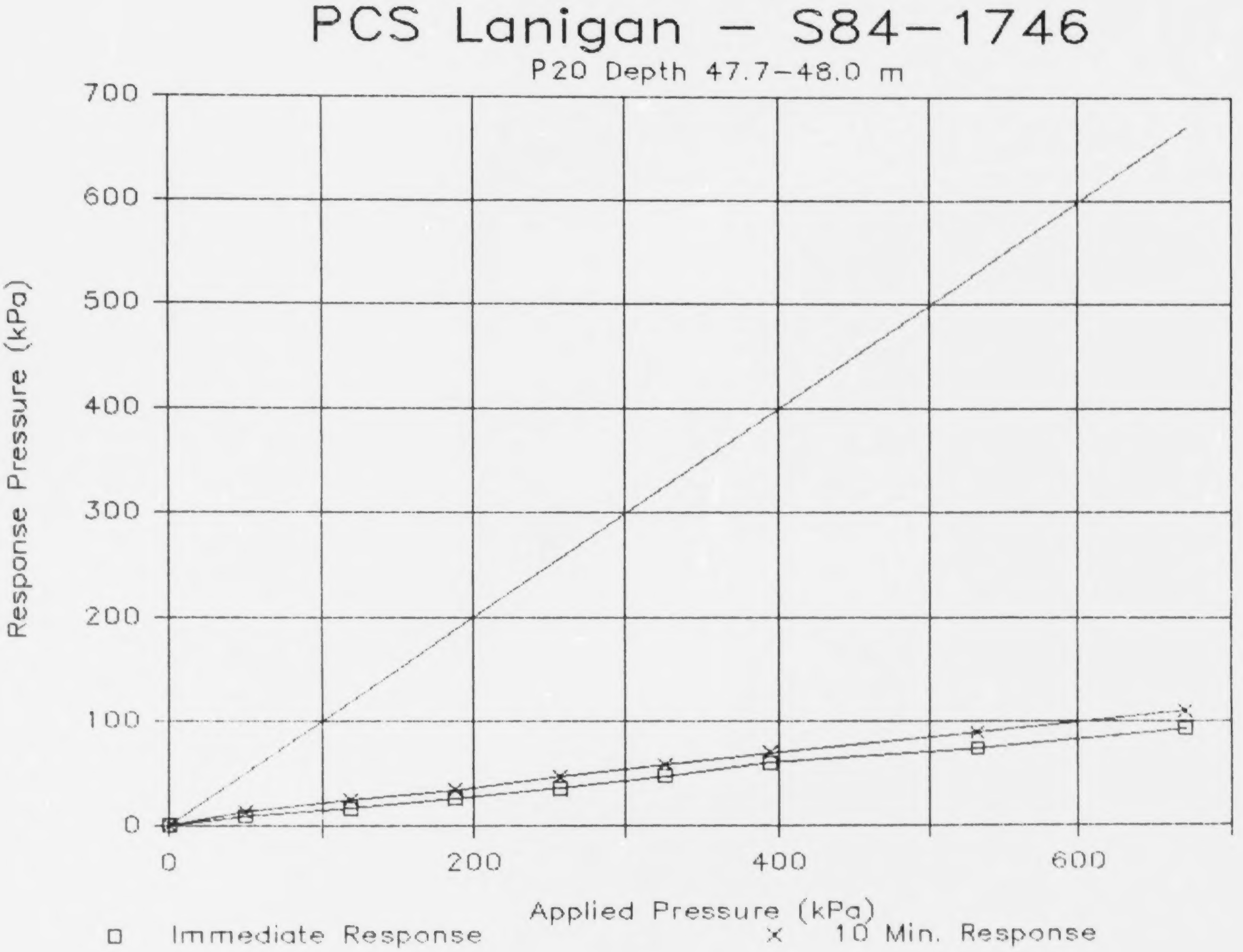
P18 Depth 12.6–13.0 m



PCS Lanigan – S84–1746

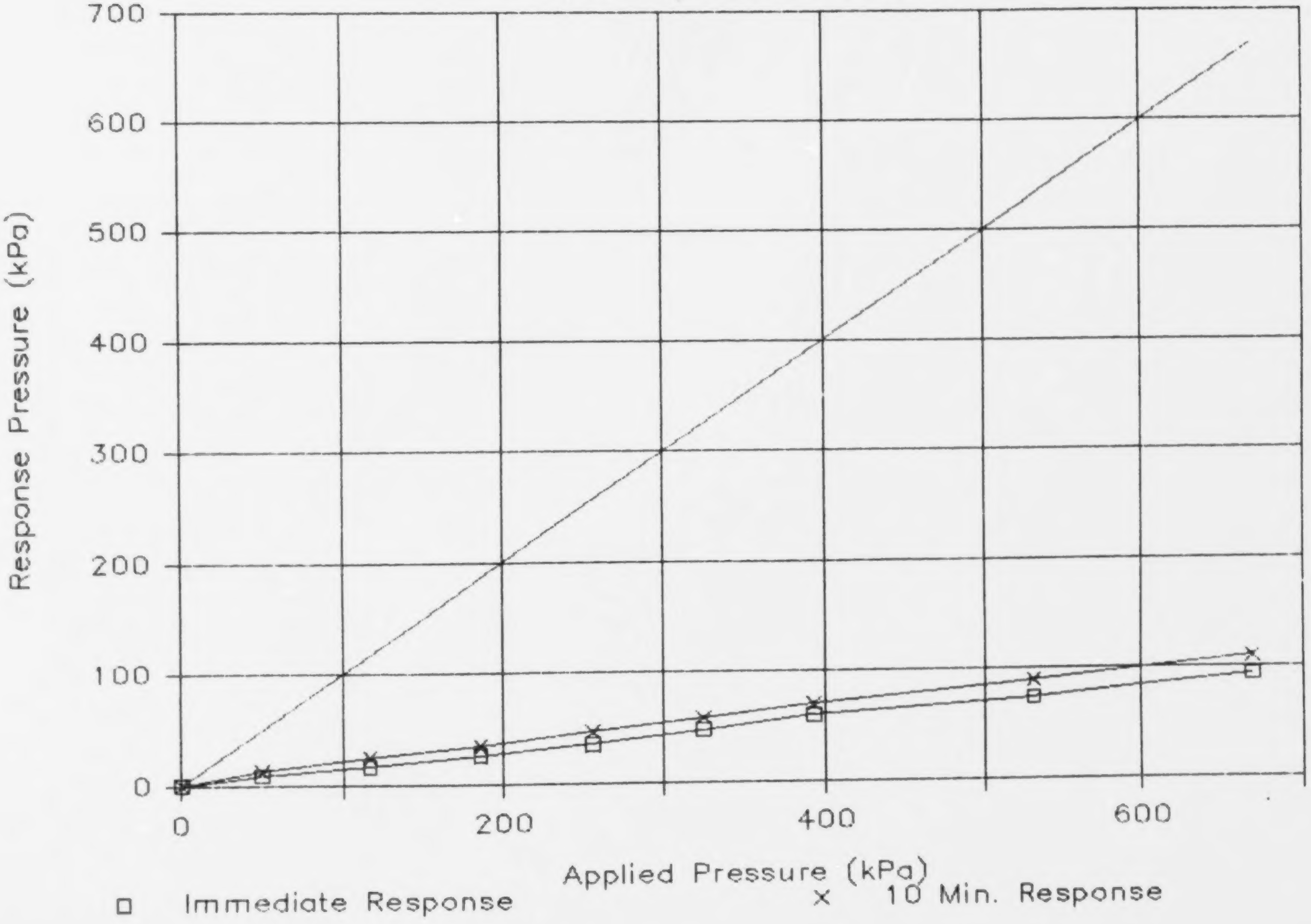
P19 Depth 25.3–25.5m

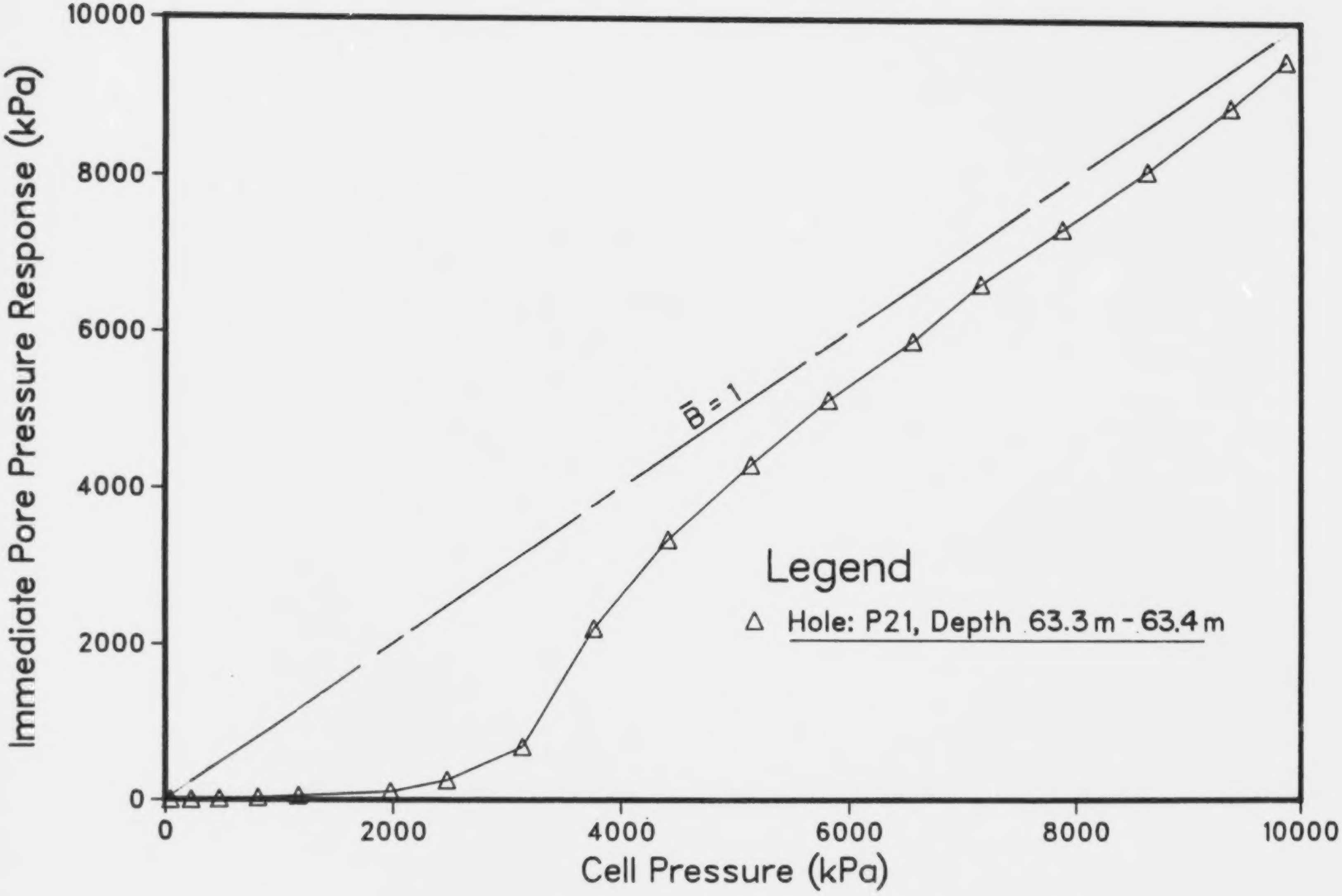



PCS Lanigan – S84–1746
P20 Depth 47.7–48.0 m
Response Pressure (kPa)
700
600
500
400
300
200
100
0
0
200
400
600
Applied Pressure (kPa)
□ Immediate Response
× 10 Min. Response

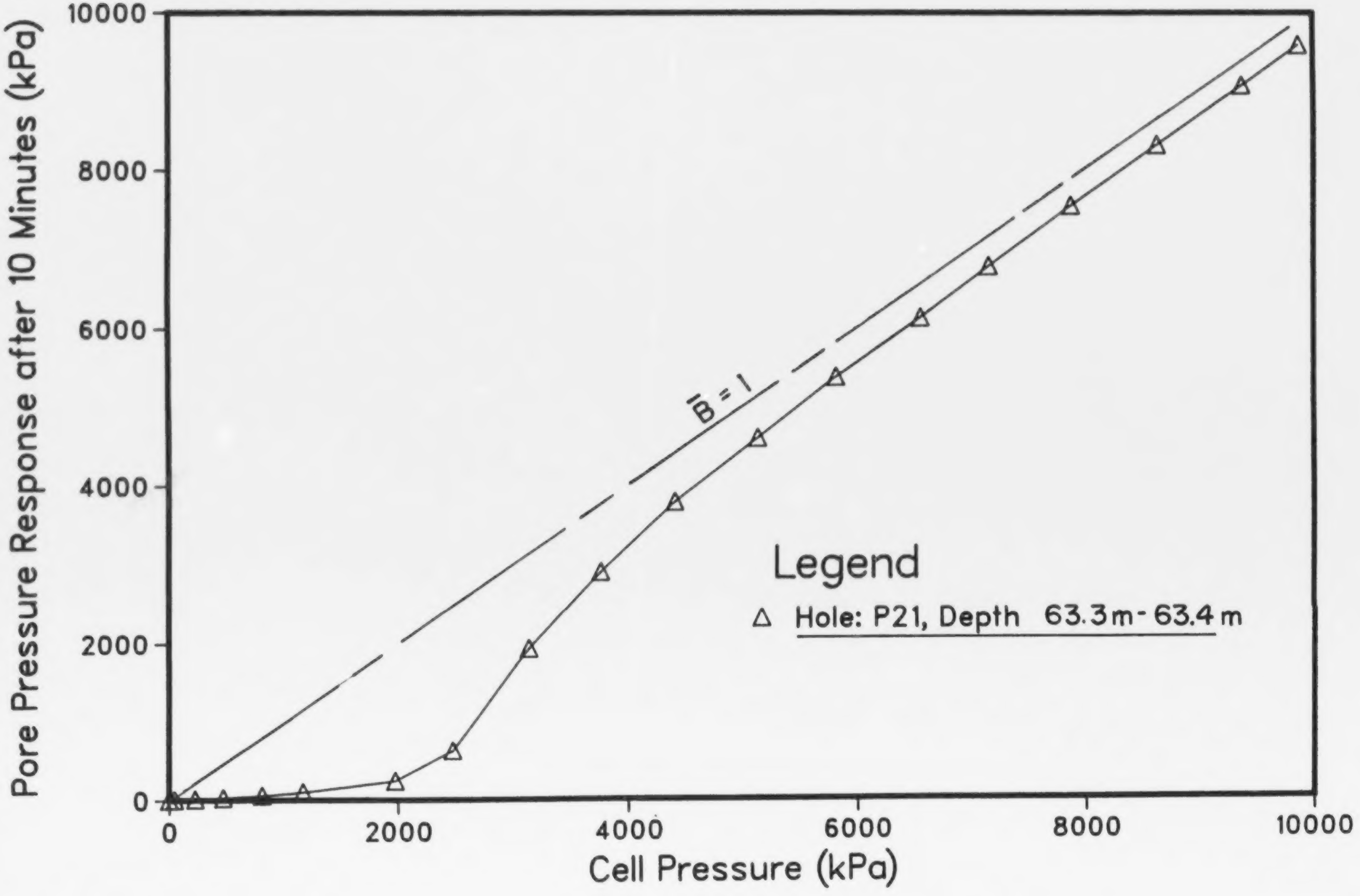
PCS Lanigan – S84–1746

P21 Depth 61.9–62.0 m





Immediate Pore Pressure Response



Pore Pressure Response after 10 Minuites

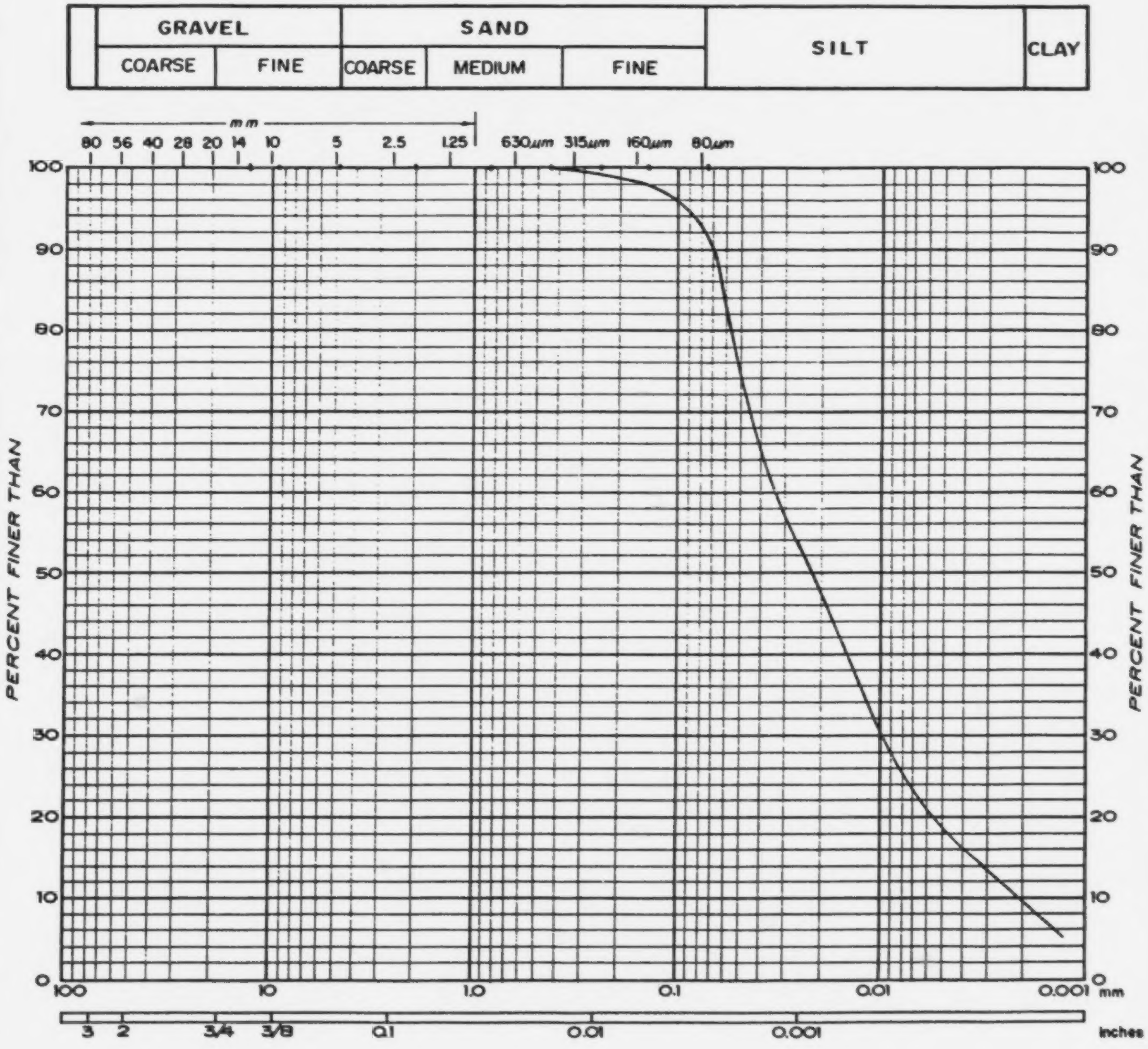
APPENDIX 5

Grain Size Distribution Curves

APPENDIX 5

Grain Size Distribution Curves

Installation	Depth (m)	Drawing No.	
P1	2.2	S84-1746-37	
P2	3.7	S84-1746-38	
P3	4.4	S84-1746-39	
P4	7.5	S84-1746-40	
P5	11.3	S84-1746-41	
P6	14.8	S84-1746-42	
P7	19.2	S84-1746-43	
P8	27.6	S84-1746-44	
P9	32.3	S84-1746-45	
P10	44.8	S84-1746-46	
P11	63.0	S84-1746-47	
P12	79.6 - 79.8 ~~99.6~~ - ~~99.8~~	S84-1746-48	Revision dated Dec 27/85
P13	90.5	S84-1746-49	
P13	91.1	S84-1746-50	
P14	112.8 - 114.3	S84-1746-51	
P14	161.5	S84-1746-52	
P15	2.1 - 2.6	S84-1746-53	
P16	3.6 - 4.0	S84-1746-54	
P17	10.1 - 10.6	S84-1746-55	
P18	12.6 - 13.0	S84-1746-56	
P19	25.5 - 25.6	S84-1746-57	
P20	47.8 - 48.1	S84-1746-58	
P21	62.1 - 62.2	S84-1746-59	



REMARKS: SILT- clayey, low plastic, some sand.

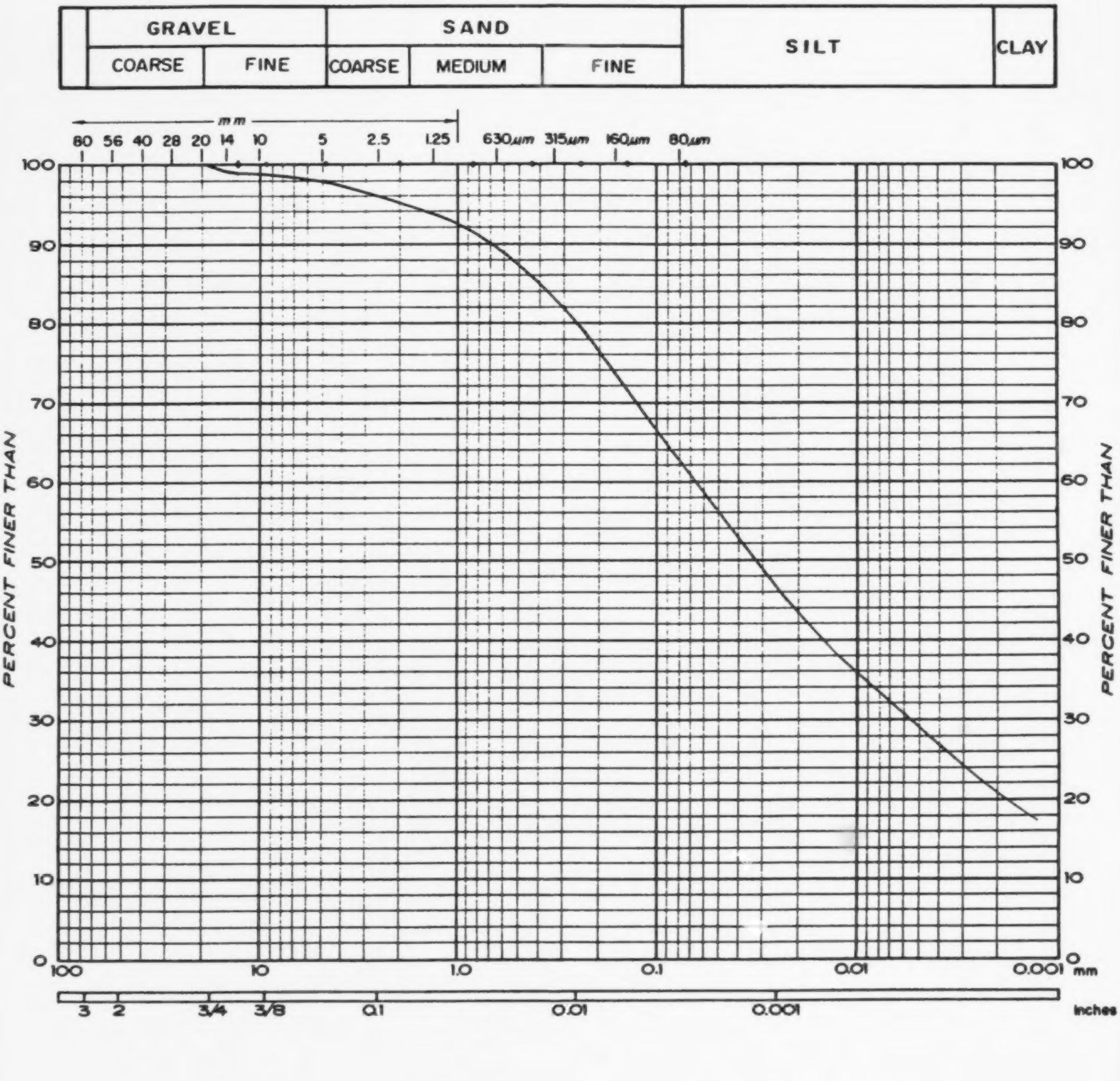
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P1 Depth 2.2m.

DRAWING NO: S84-1746-37



REMARKS: CLAY TILL - silty, moist, low plastic, oxides.

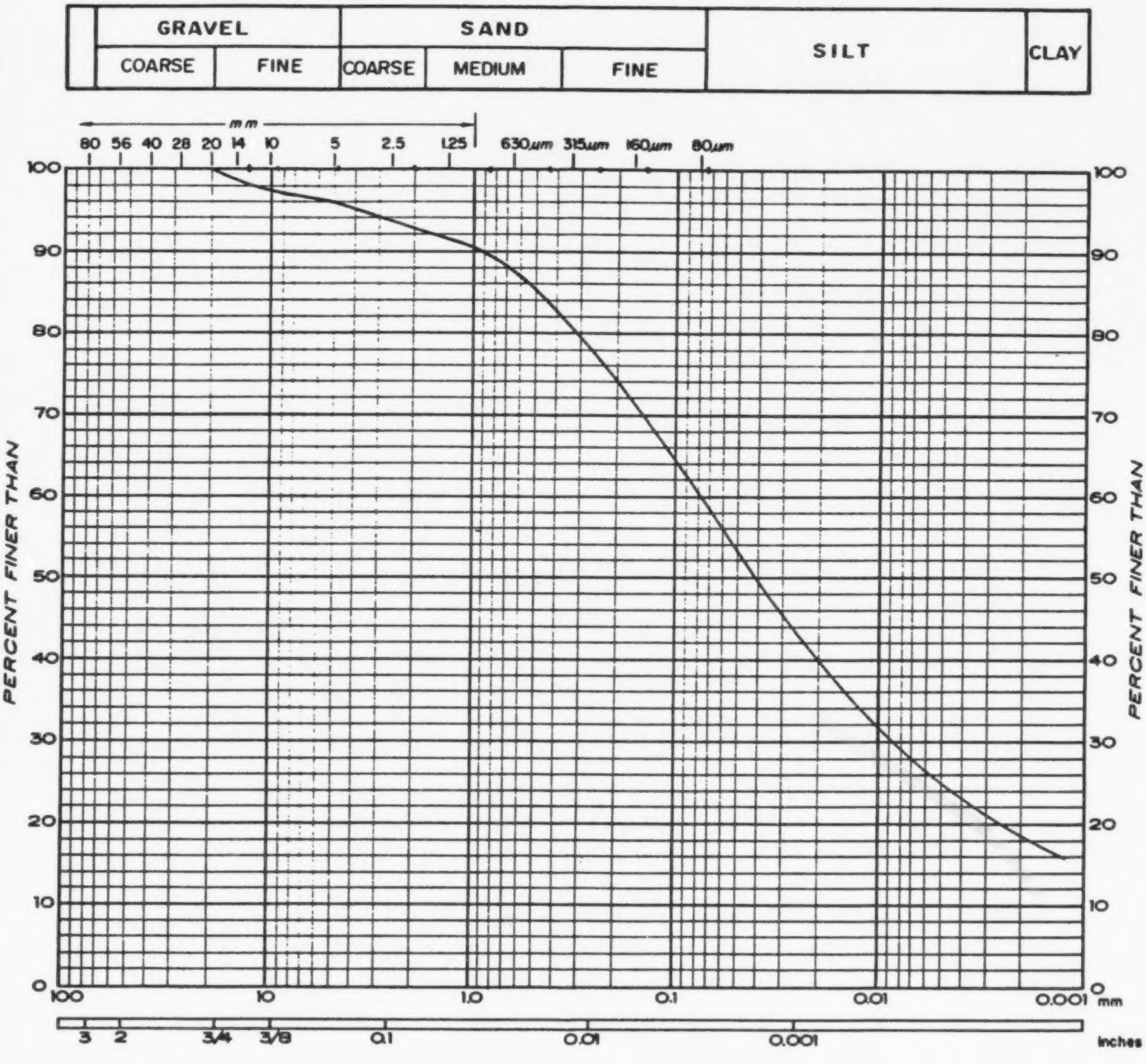
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P2 Depth 3.7m

DRAWING NO: S84-1746-38



REMARKS: CLAY TILL - moist, very stiff, low plastic, grey-brown, oxides

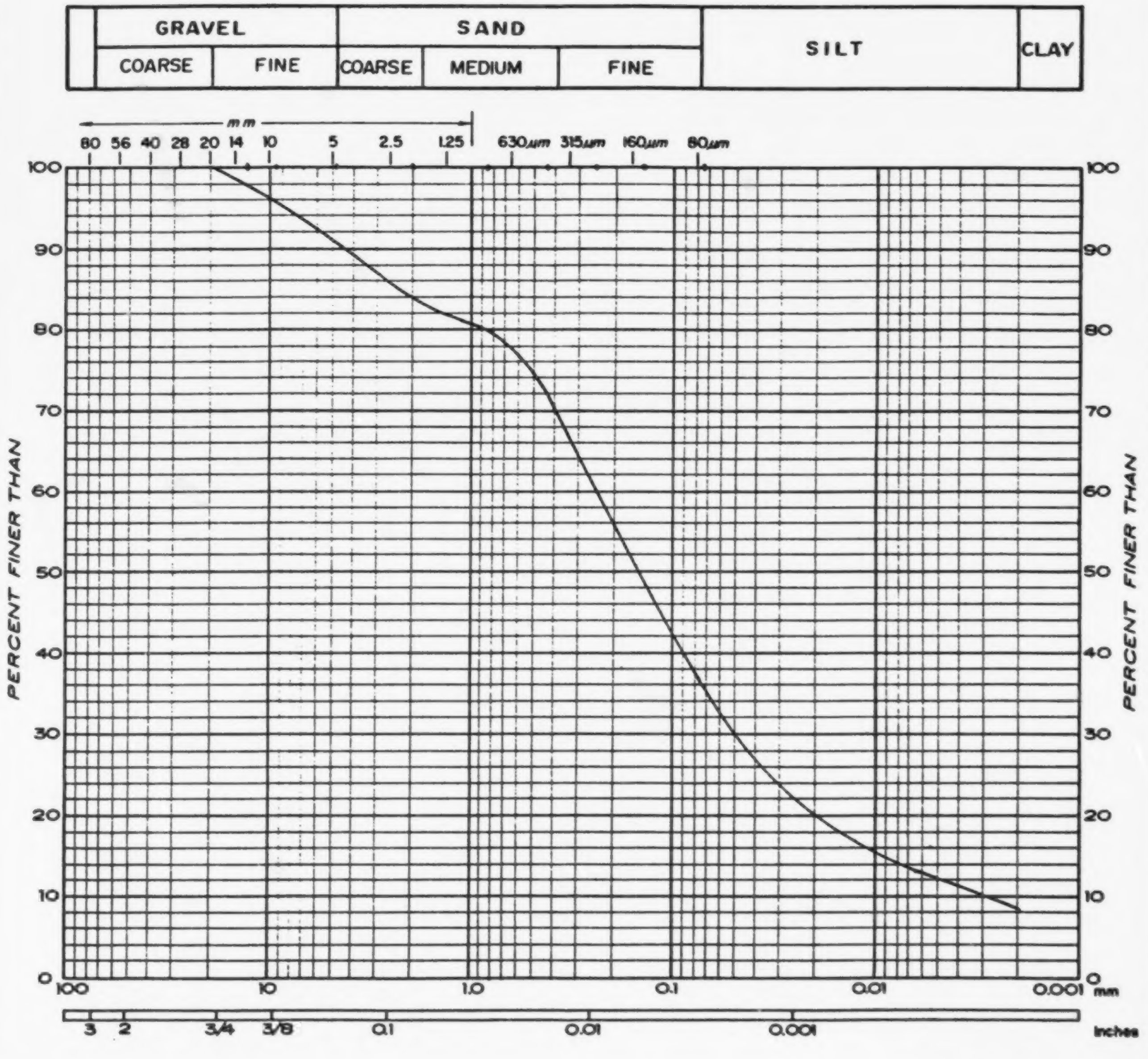
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P3 Depth 4.4m

DRAWING NO: S84-1746-39



REMARKS: *CLAY TILL - silty, wet, stiff, low plastic, sand lenses*

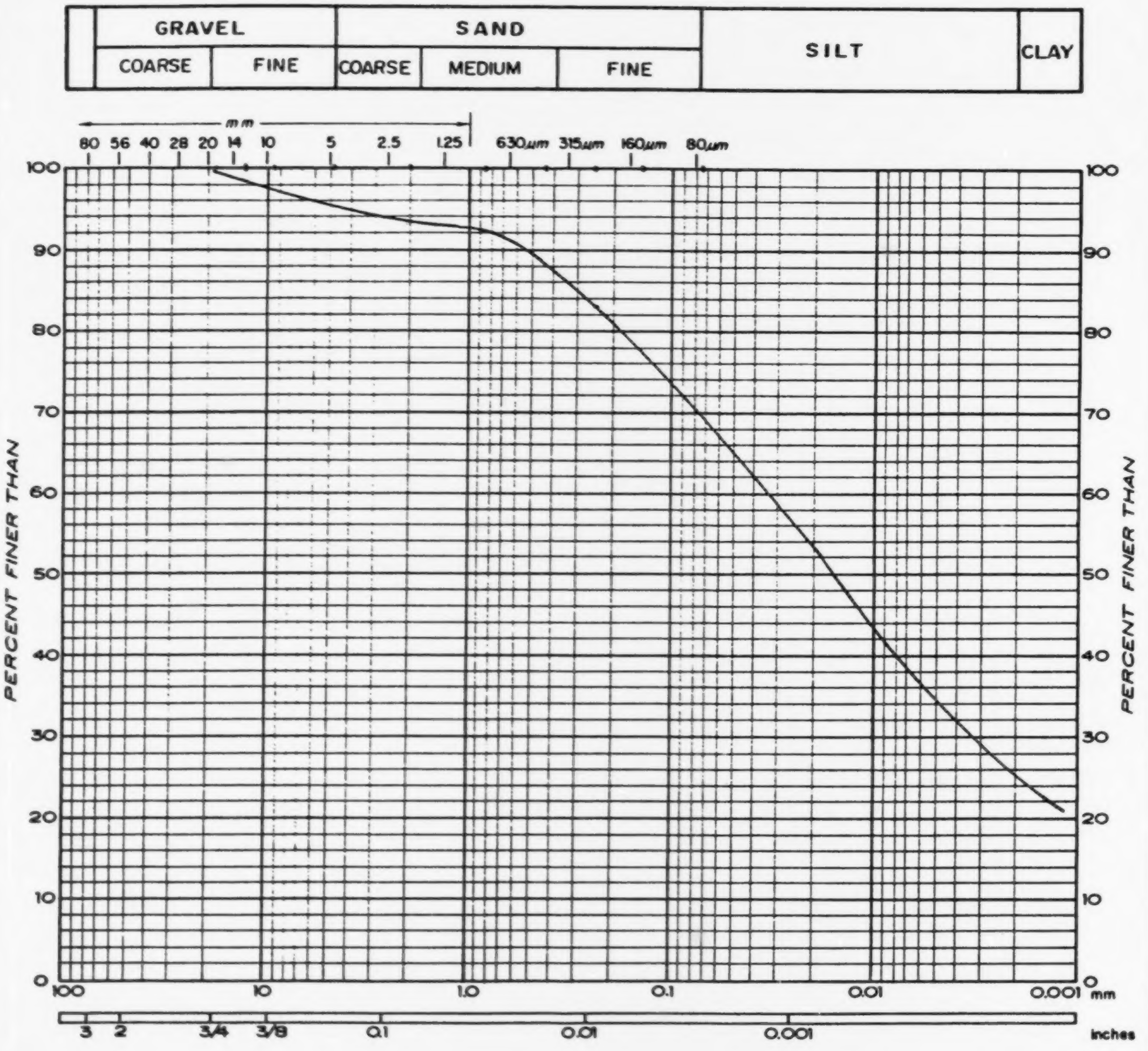
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. *P4* Depth *7.5m*

DRAWING NO: S84-1746-40



REMARKS : CLAY TILL - moist, stiff to very stiff, medium plastic, grey, wet sand pockets

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

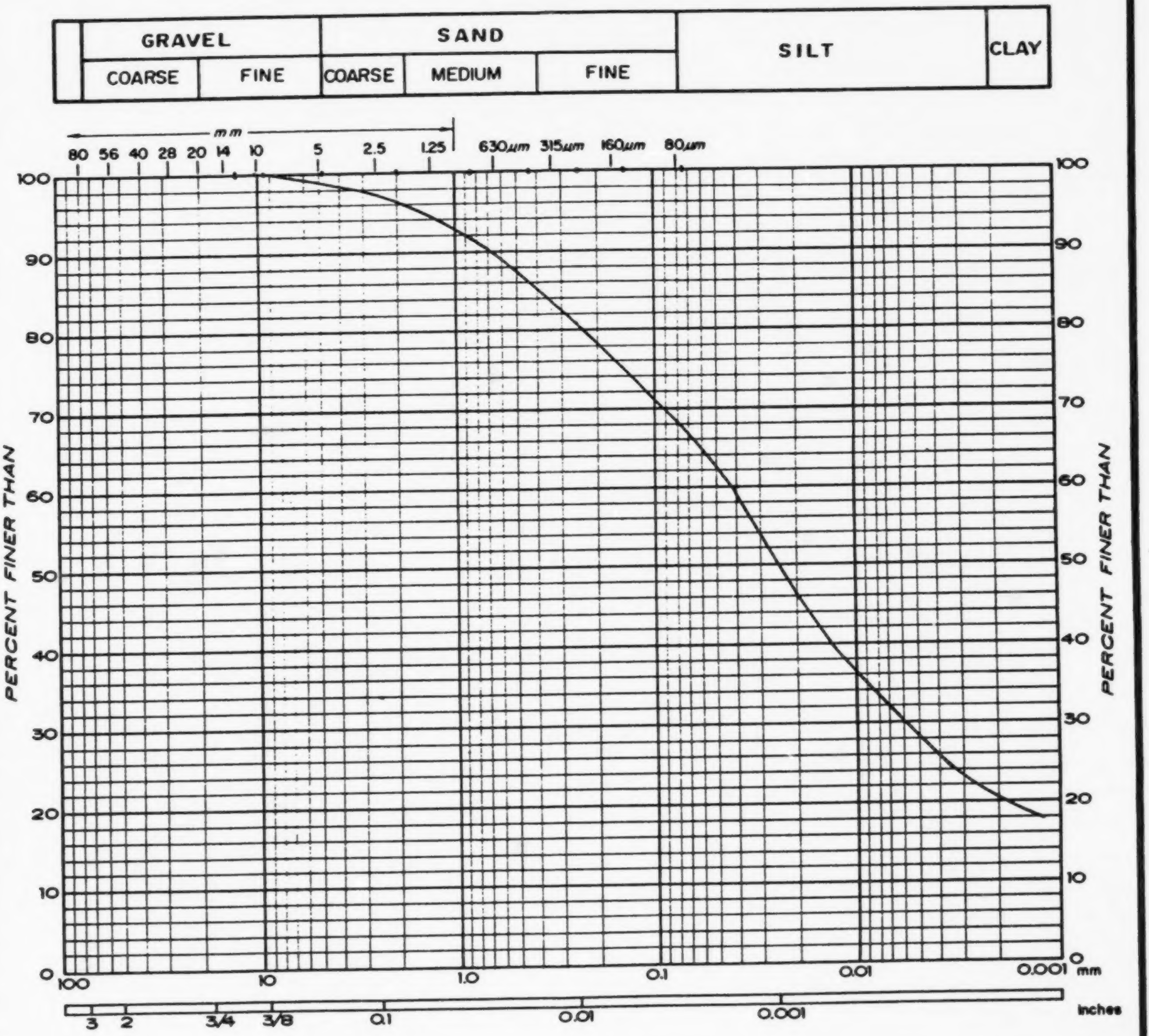
Tails Pile Instrumentation

PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P5 Depth 11.3m

DRAWING NO: S84-1746-41



REMARKS : CLAY TILL - moist, very stiff, medium plastic, grey.

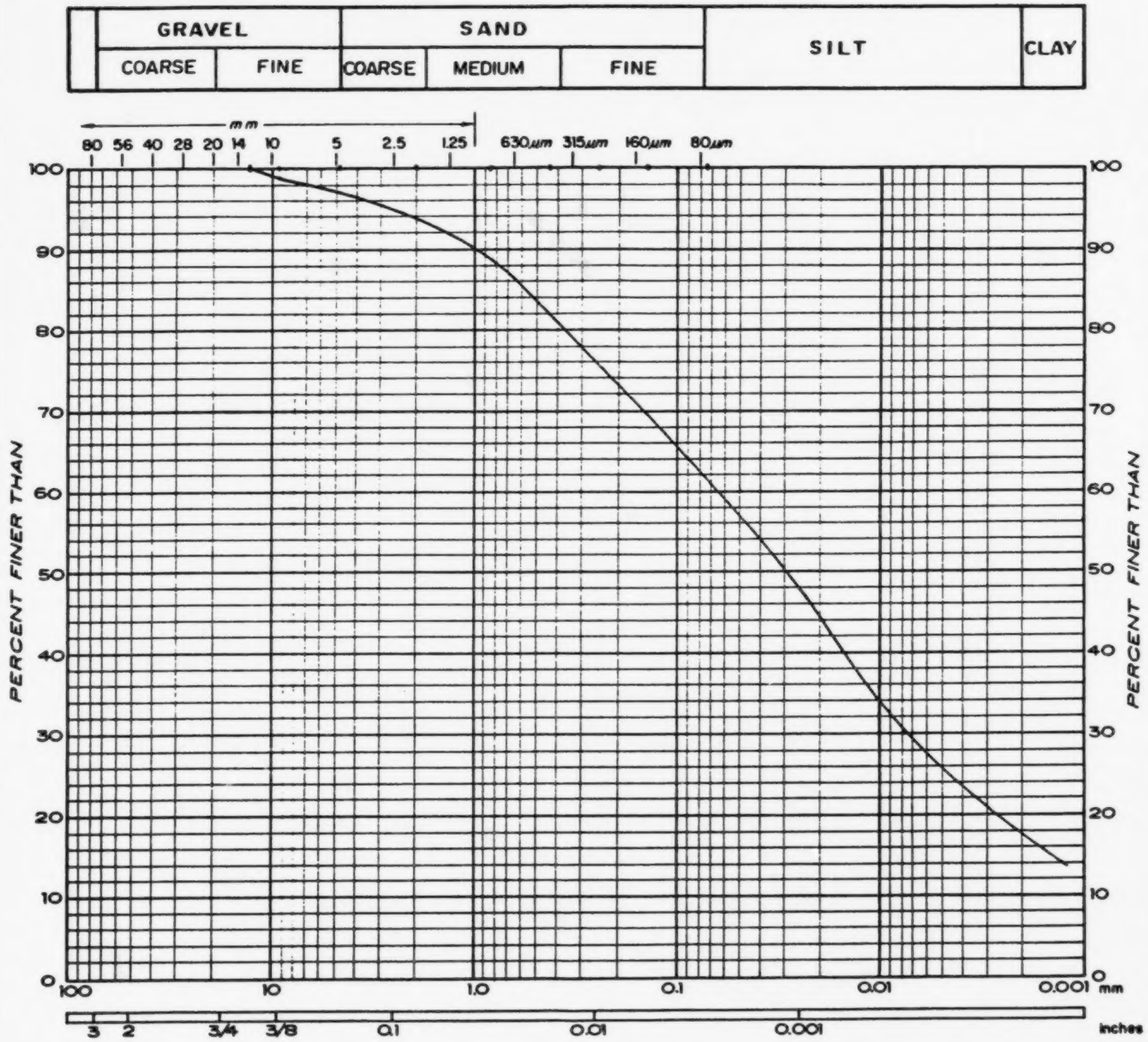
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P6 Depth 14.8m

DRAWING NO:
S84-1746-42



REMARKS: CLAY TILL - moist, very stiff to hard, low plastic, grey.

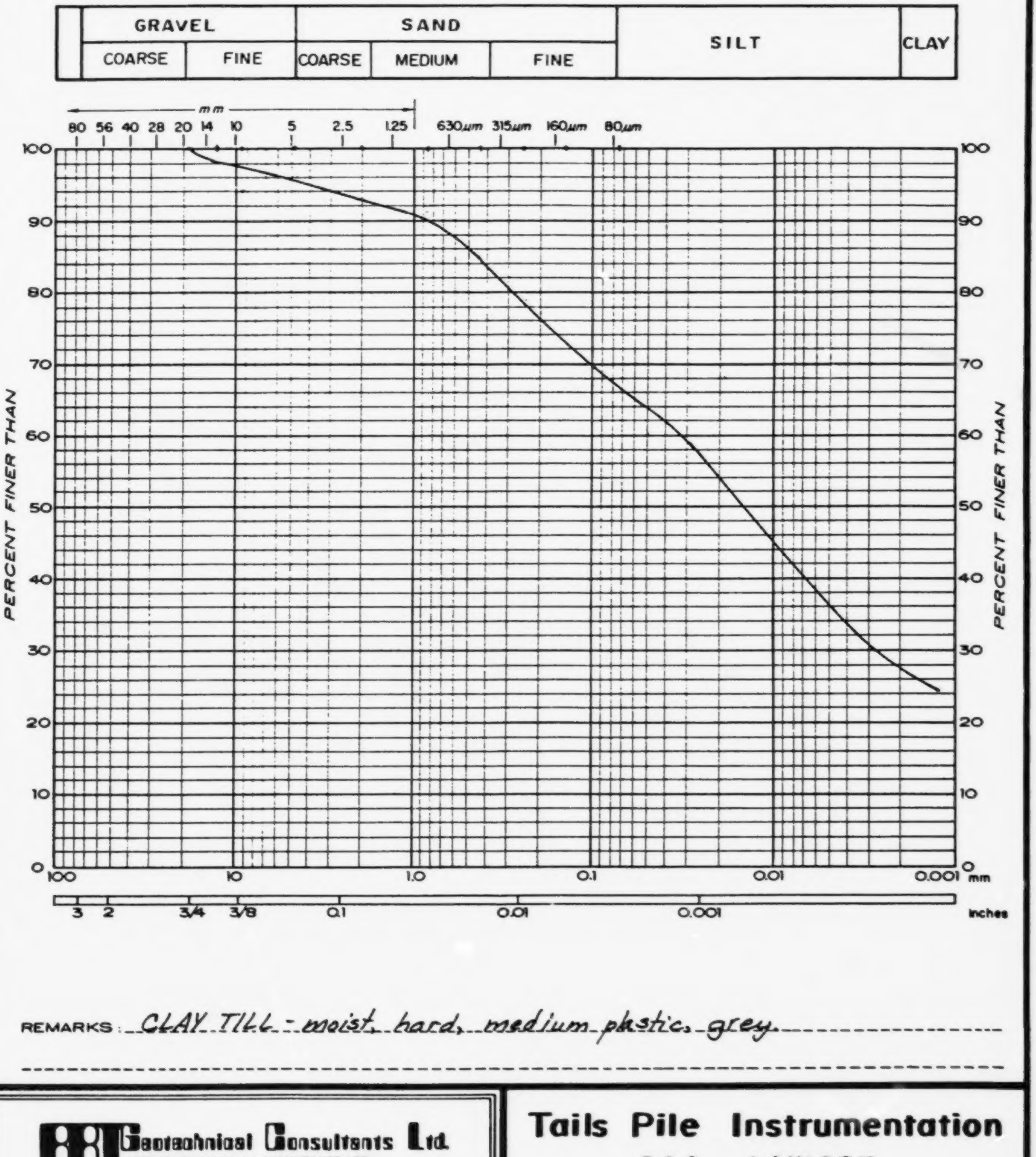
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P7 Depth 19.2m

DRAWING NO:
S84-1746-43



REMARKS: CLAY TILL - moist, hard, medium plastic, grey.

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

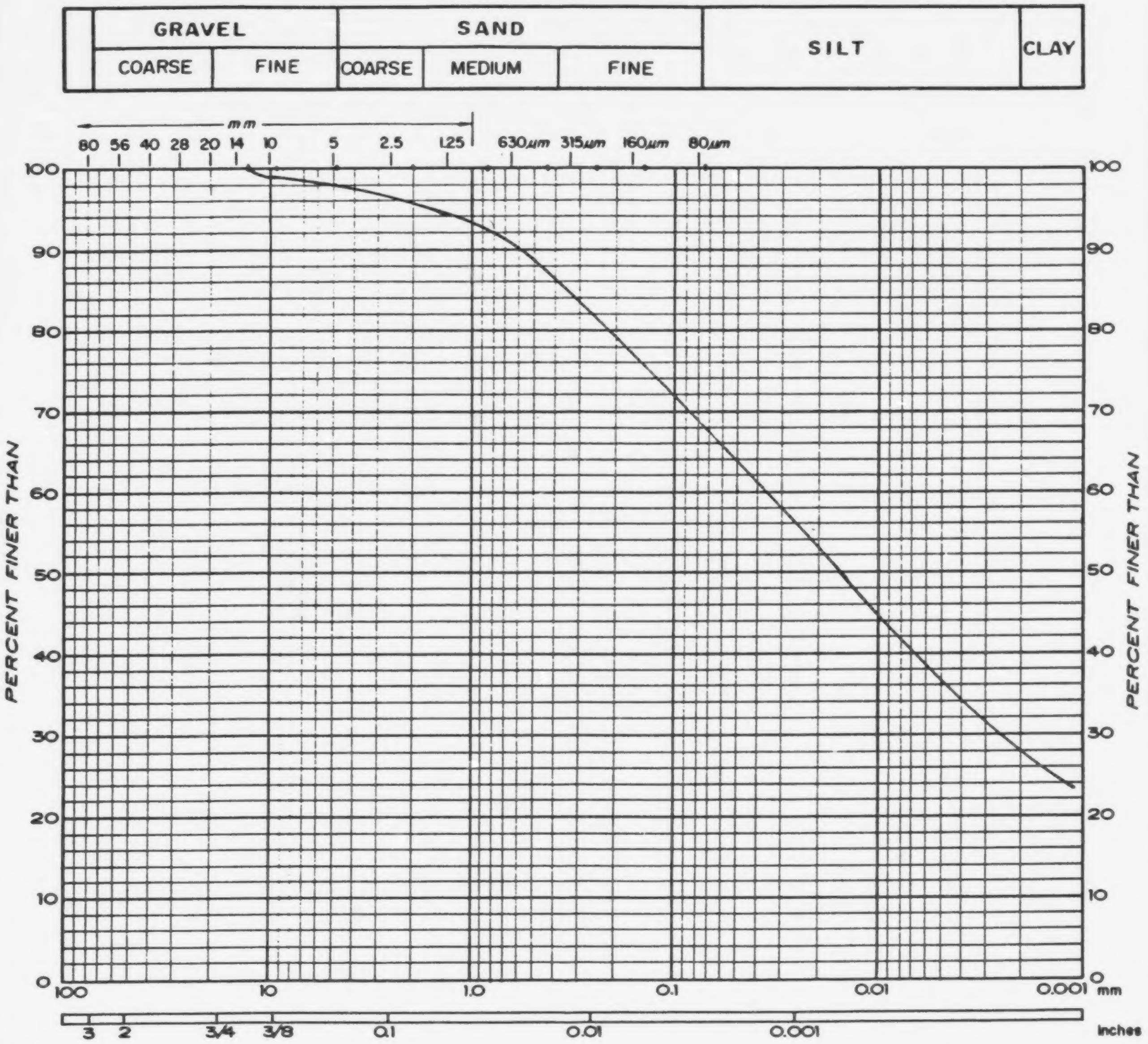
Tails Pile Instrumentation

PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P8 Depth 27.6m

DRAWING NO: S84-1746-44



REMARKS: CLAY TILL- moist, hard, medium plastic, grey.

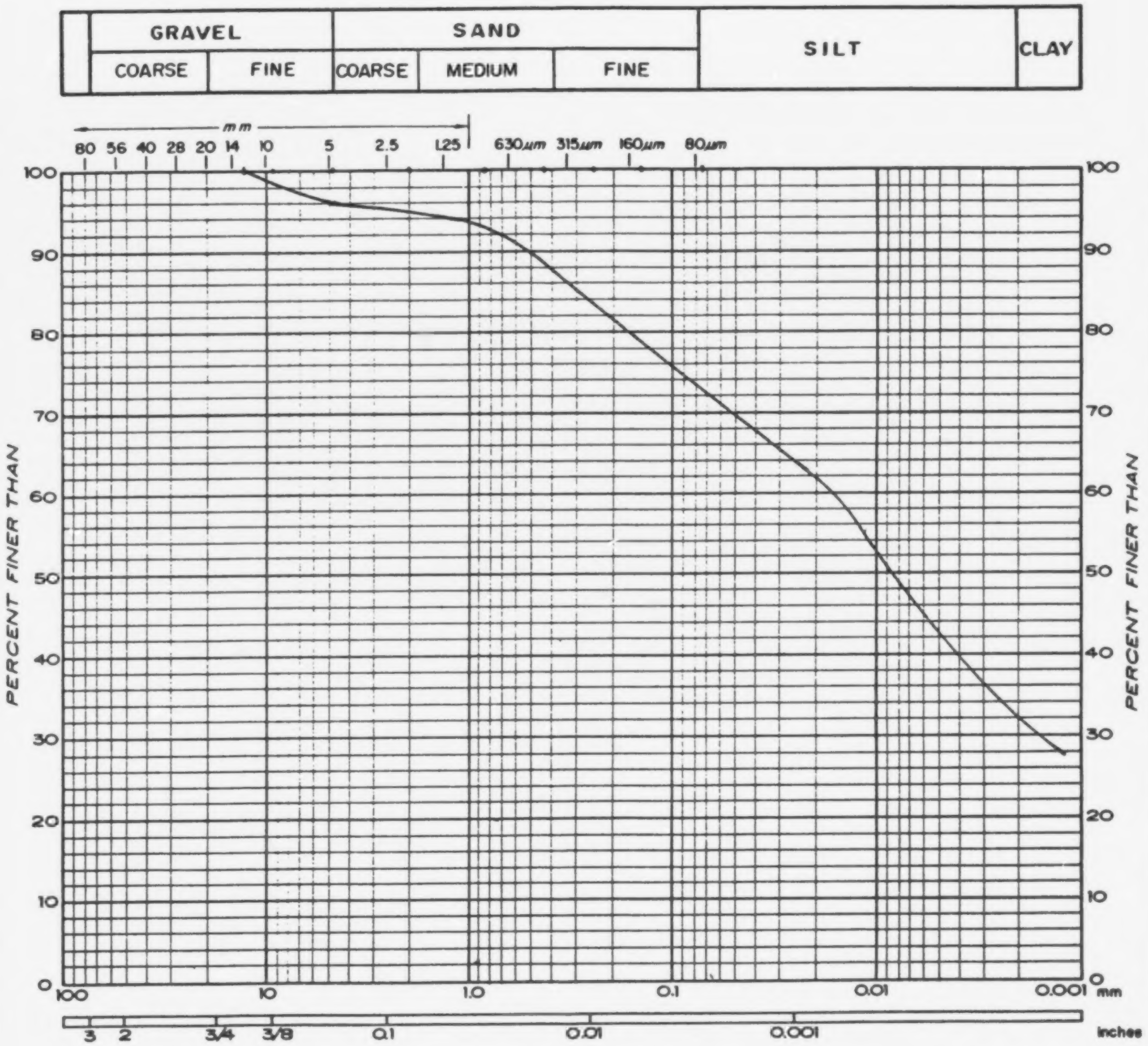
BBT Geotechnical Consultants Ltd
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P9 Depth 32.3m

DRAWING NO: S84-1746-45



REMARKS: CLAY TILL - damp to moist, hard, medium plastic, grey.

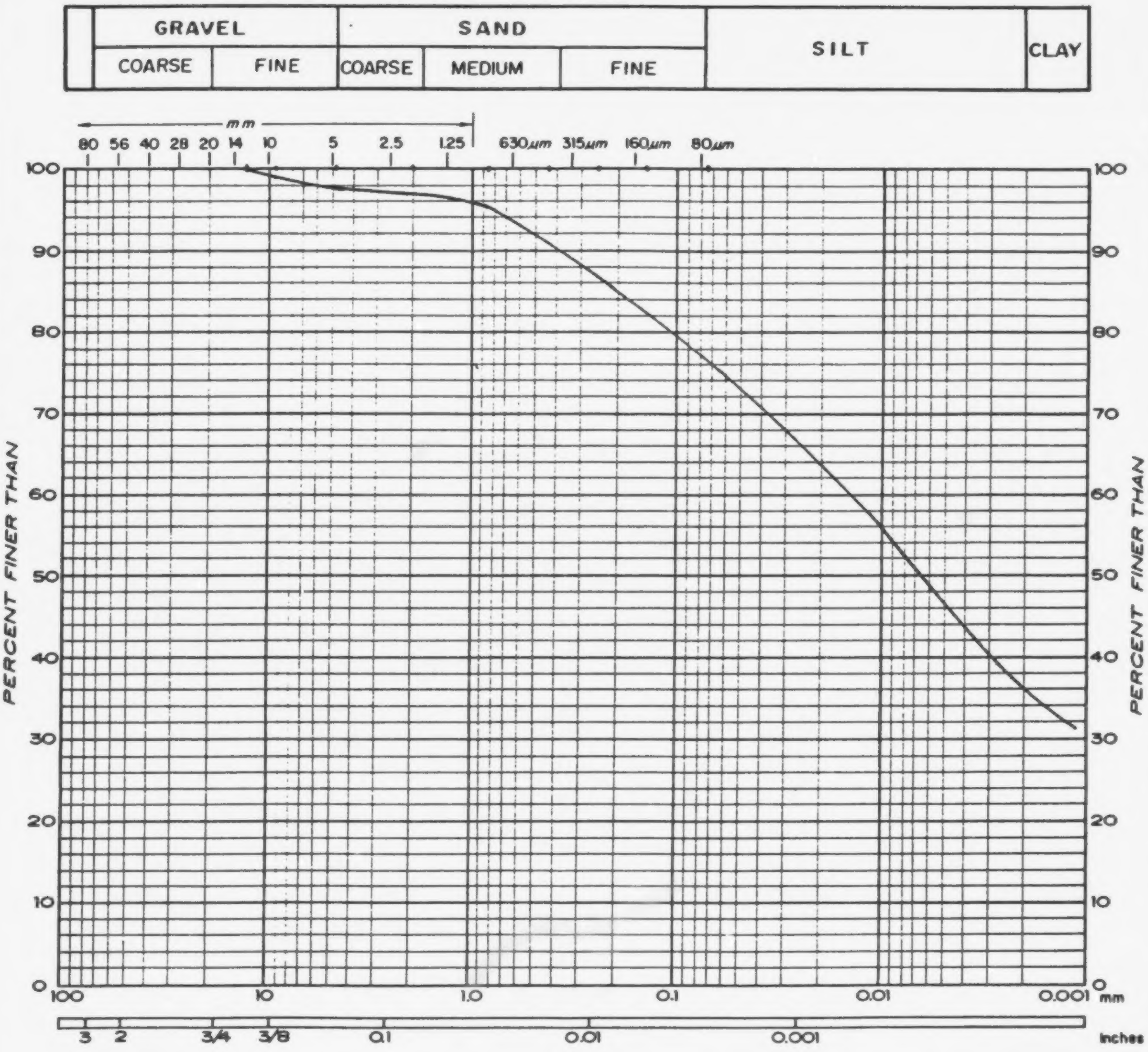
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P10 Depth 44.8m

DRAWING NO: S84-1746-46



REMARKS: CLAY TILL - damp, hard, medium plastic, grey

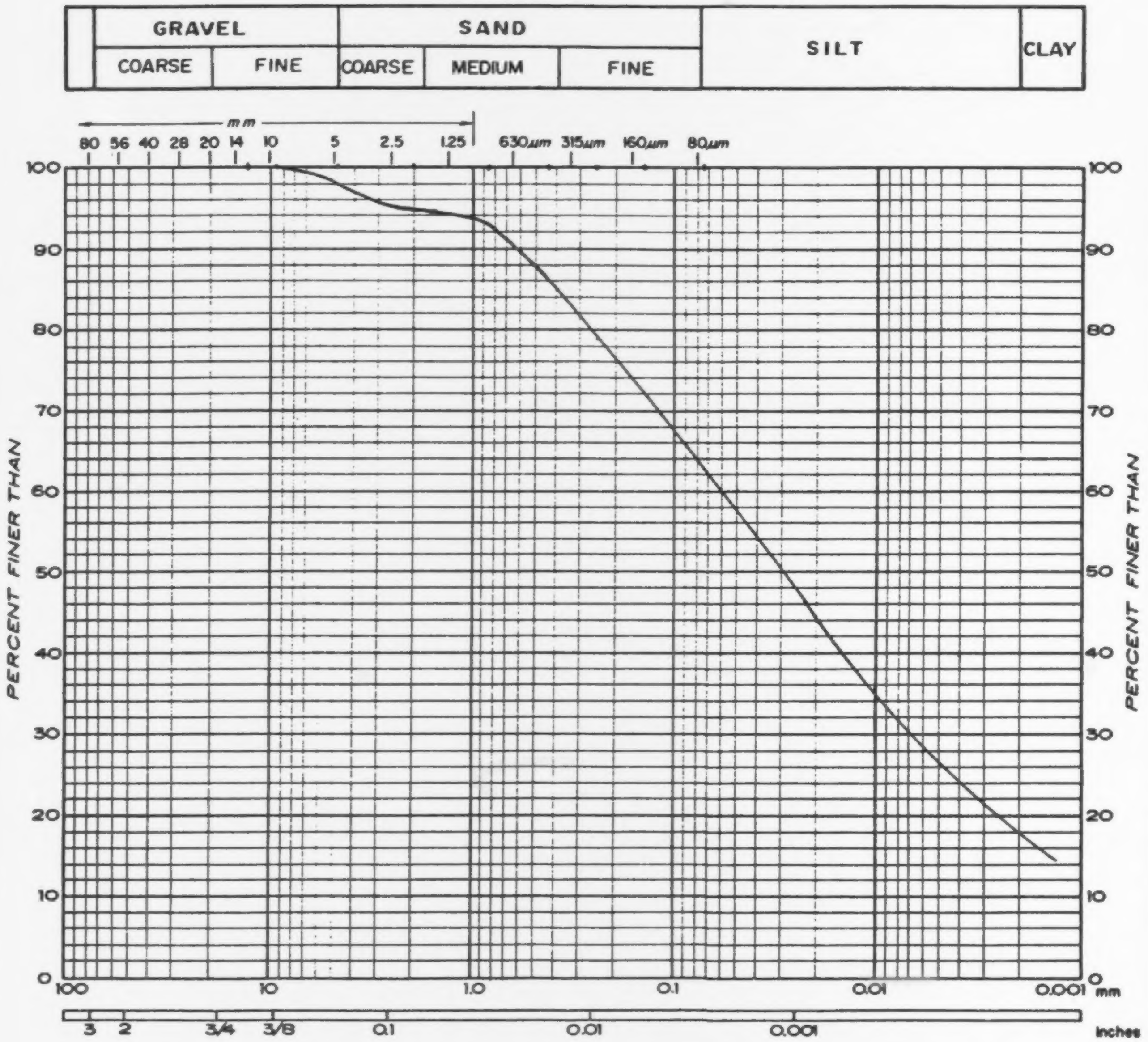
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P11 Depth 63.0m

DRAWING NO:
S84-1746-47



REMARKS: *CLAY TILL - damp, hard, low plastic, grey*

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation

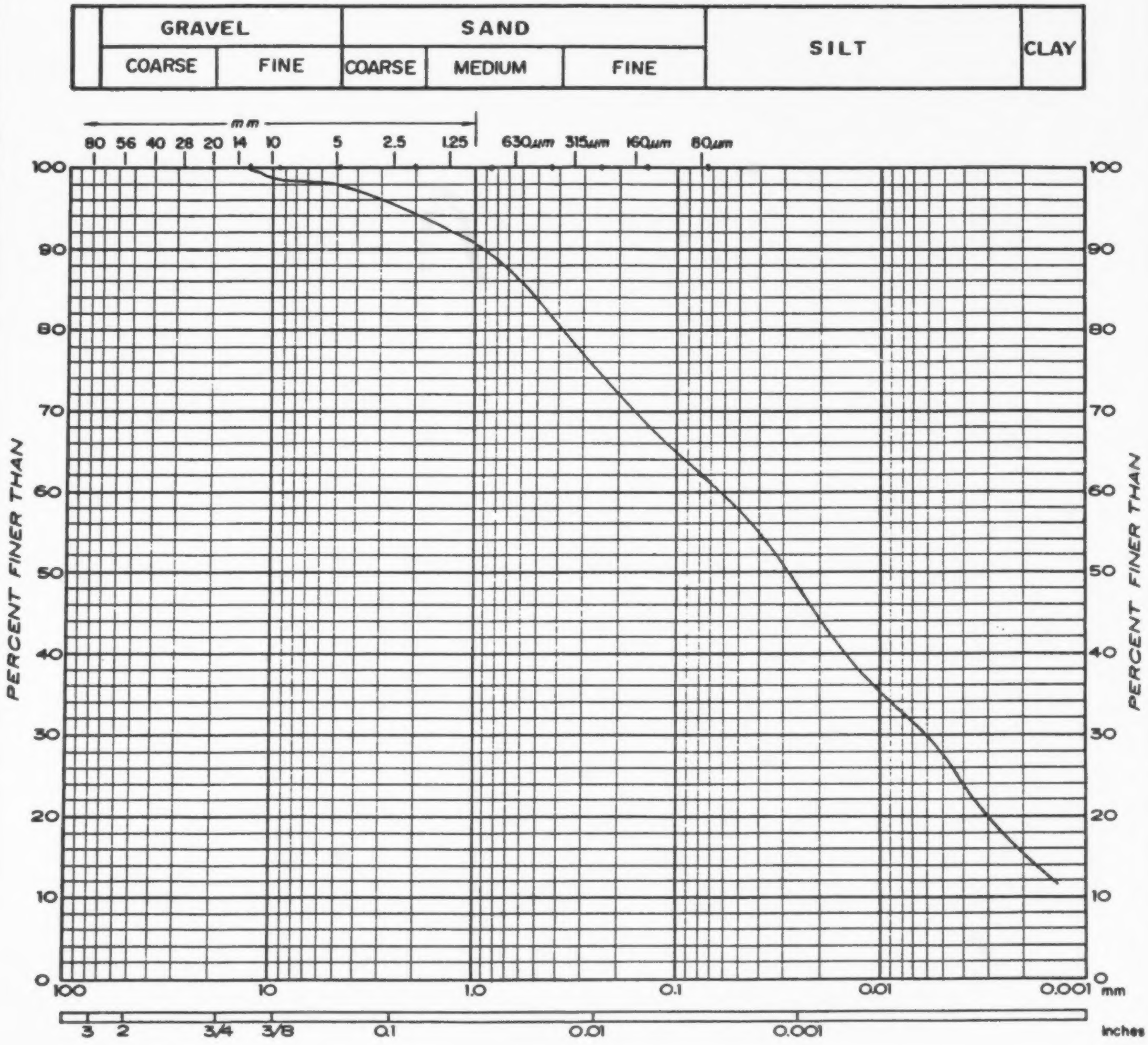
PCS LANIGAN

Revision dated Dec 27/85

GRAIN SIZE DISTRIBUTION

Test Hole No. P12 Depth ~~[illegible]~~ 79.6 - 79.8

DRAWING NO: S84-1746-48



REMARKS: CLAY TILL - moist, hard, medium plastic, grey

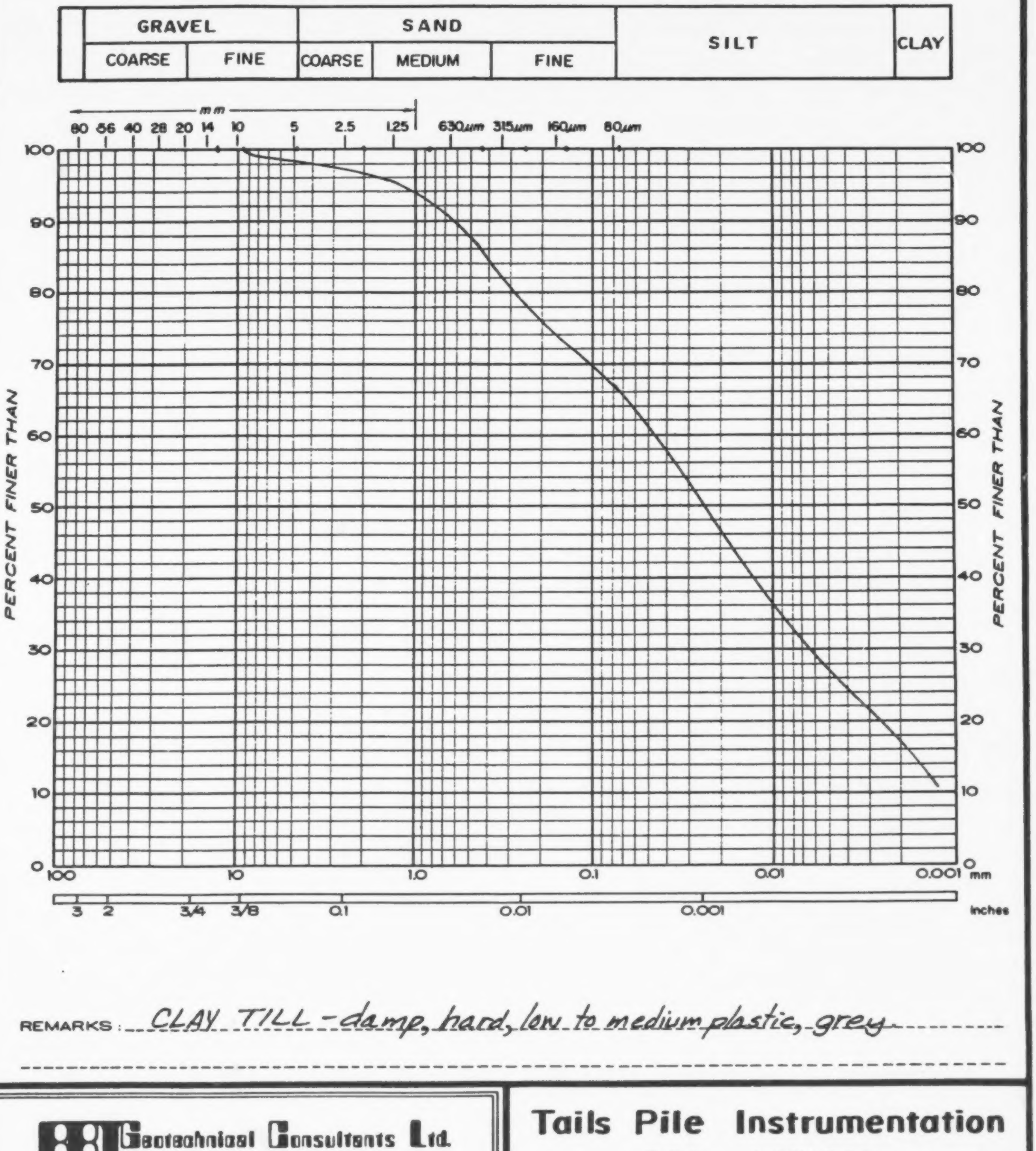
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P13 Depth 90.5 m

DRAWING NO: S84-1746-49



REMARKS: CLAY TILL - damp, hard, low to medium plastic, grey

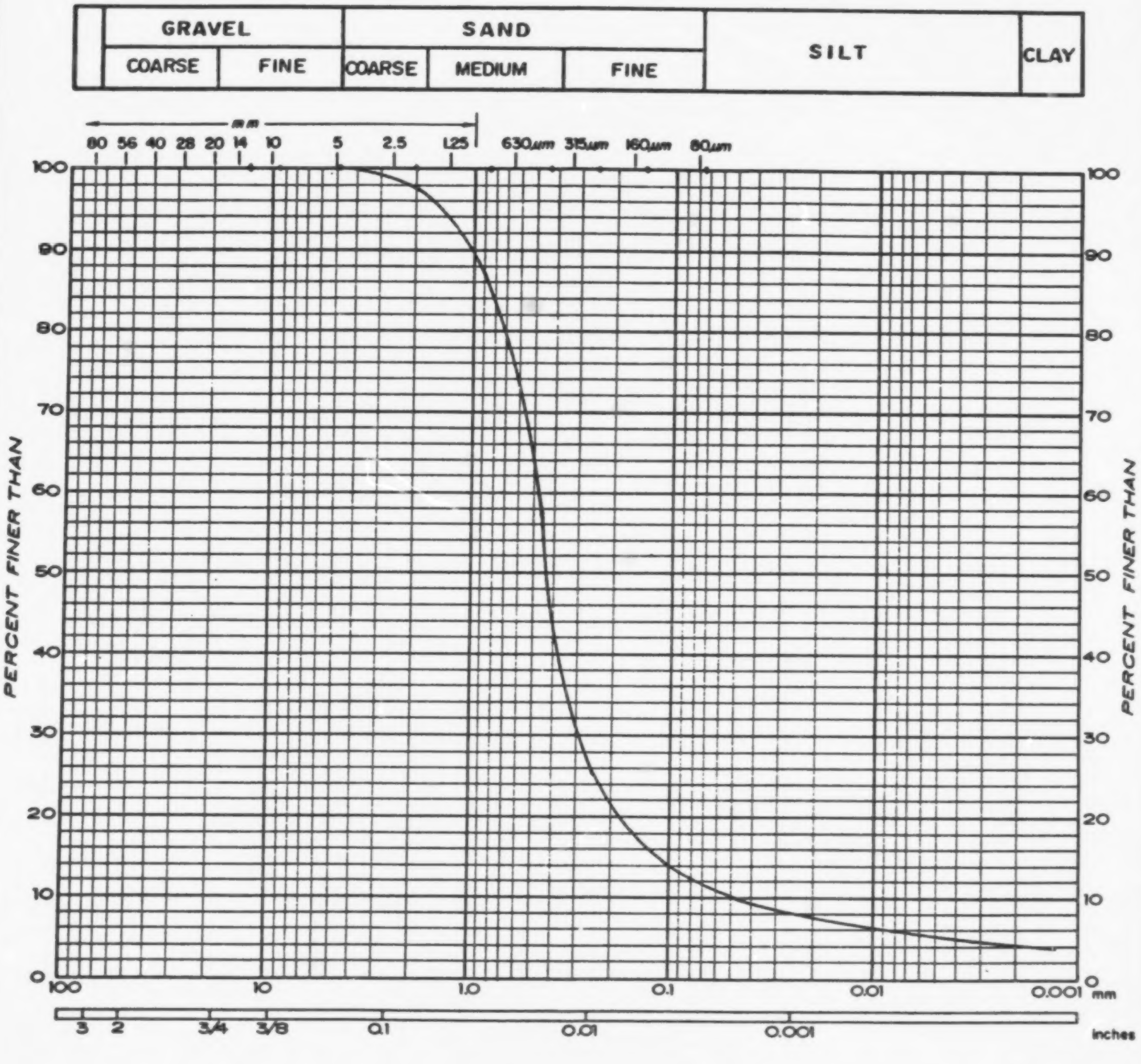
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation

PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P13	Depth 91.1m	DRAWING NO: S84-1746-50



REMARKS: SAND - wet, dense, medium grained, poorly graded, grey.
somefine sand, some silt.

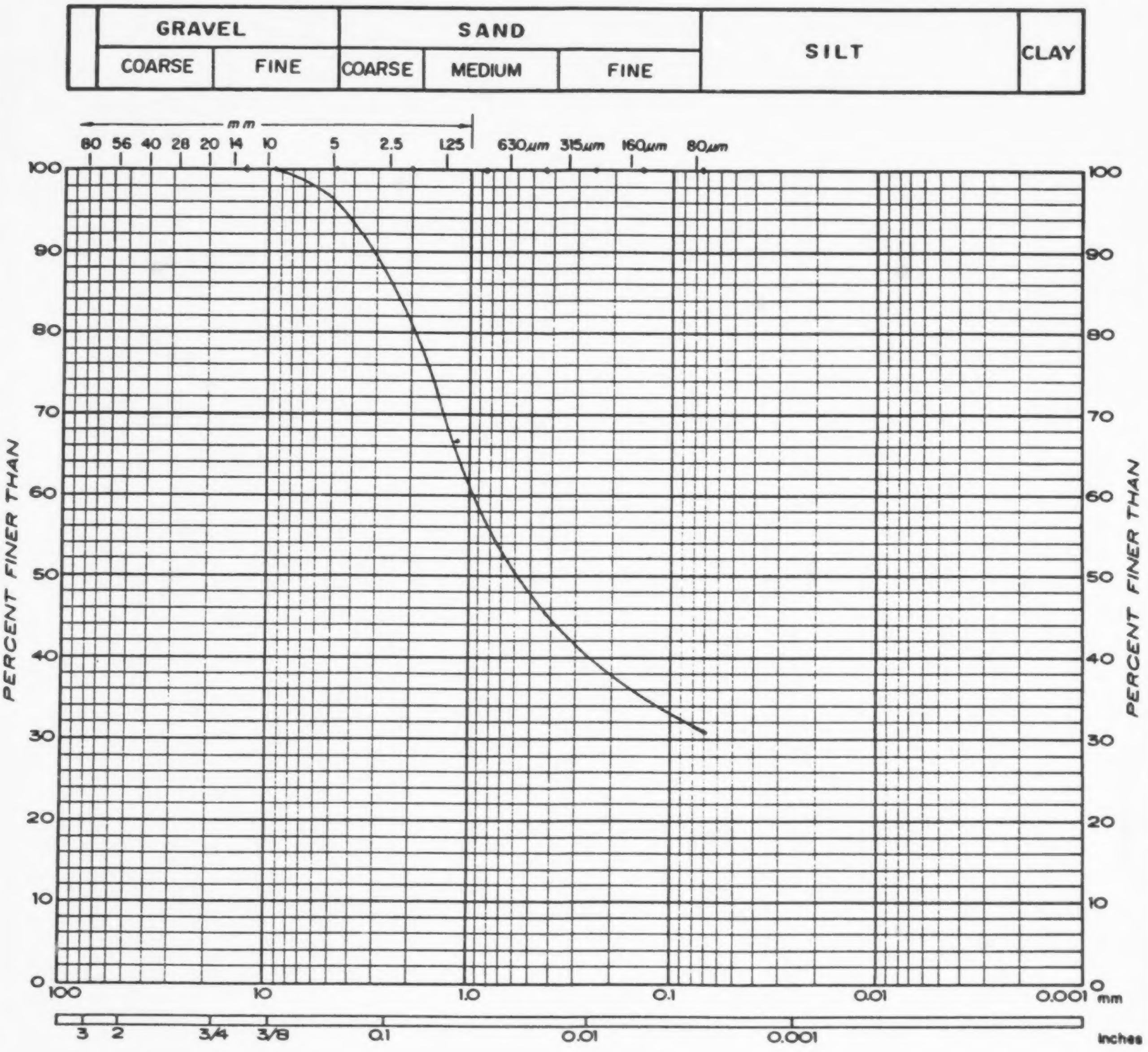
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P14 Depth 112.8-114.3m

DRAWING NO:
S84-1746-51



REMARKS: CLAY TILL - sandy, silty, hard, low plastic, grey

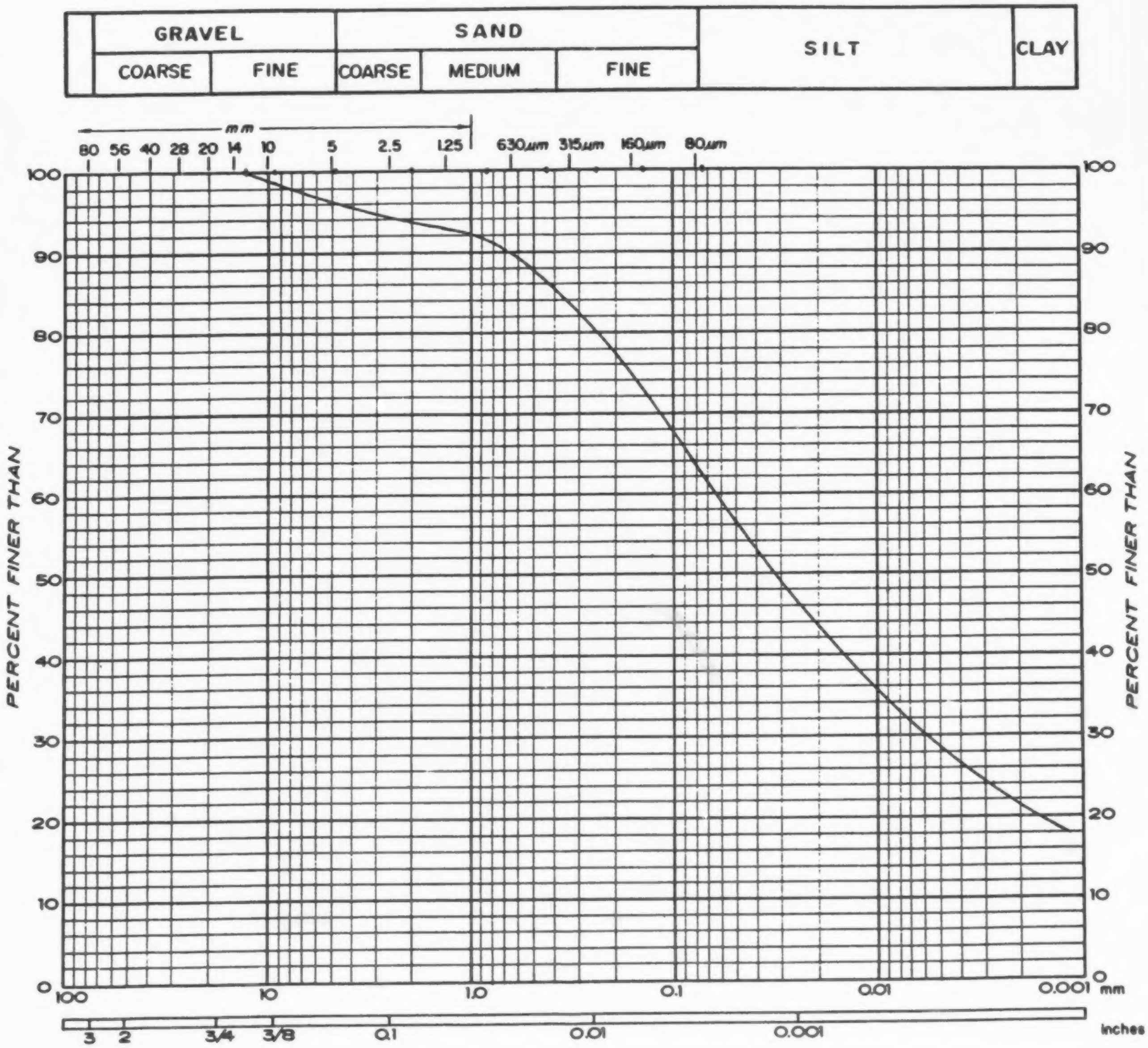
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P14 Depth 161.5m

DRAWING NO:
S84-1746-52



REMARKS: *CLAY TILL - moist, very stiff, low plastic, mottled brown, oxides.*

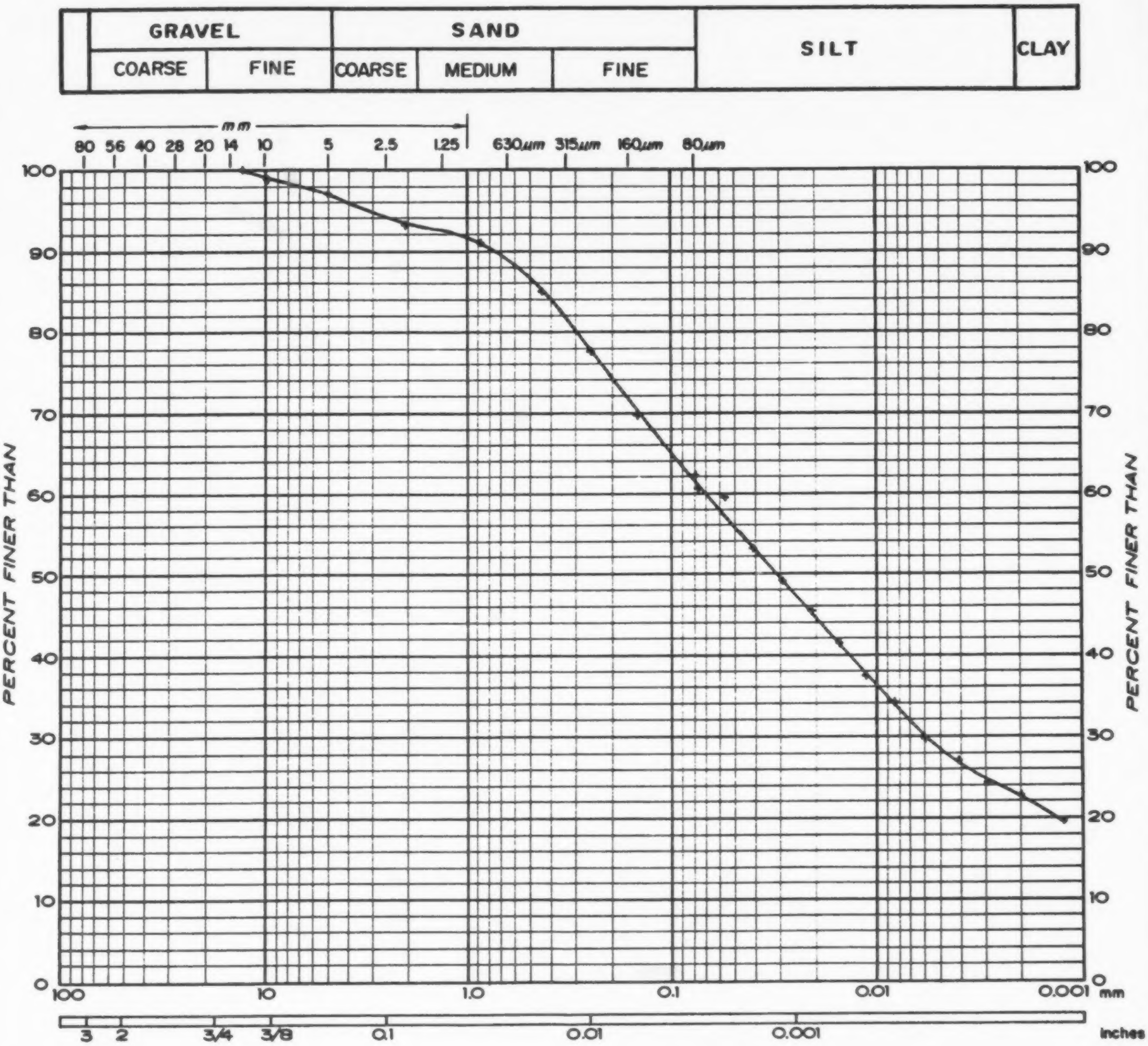
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. *P15* Depth *2.1m-2.6m*

DRAWING NO: S84-1746-53



REMARKS : CLAY TILL - moist, very stiff, low to medium plastic, mottled grey-brown.

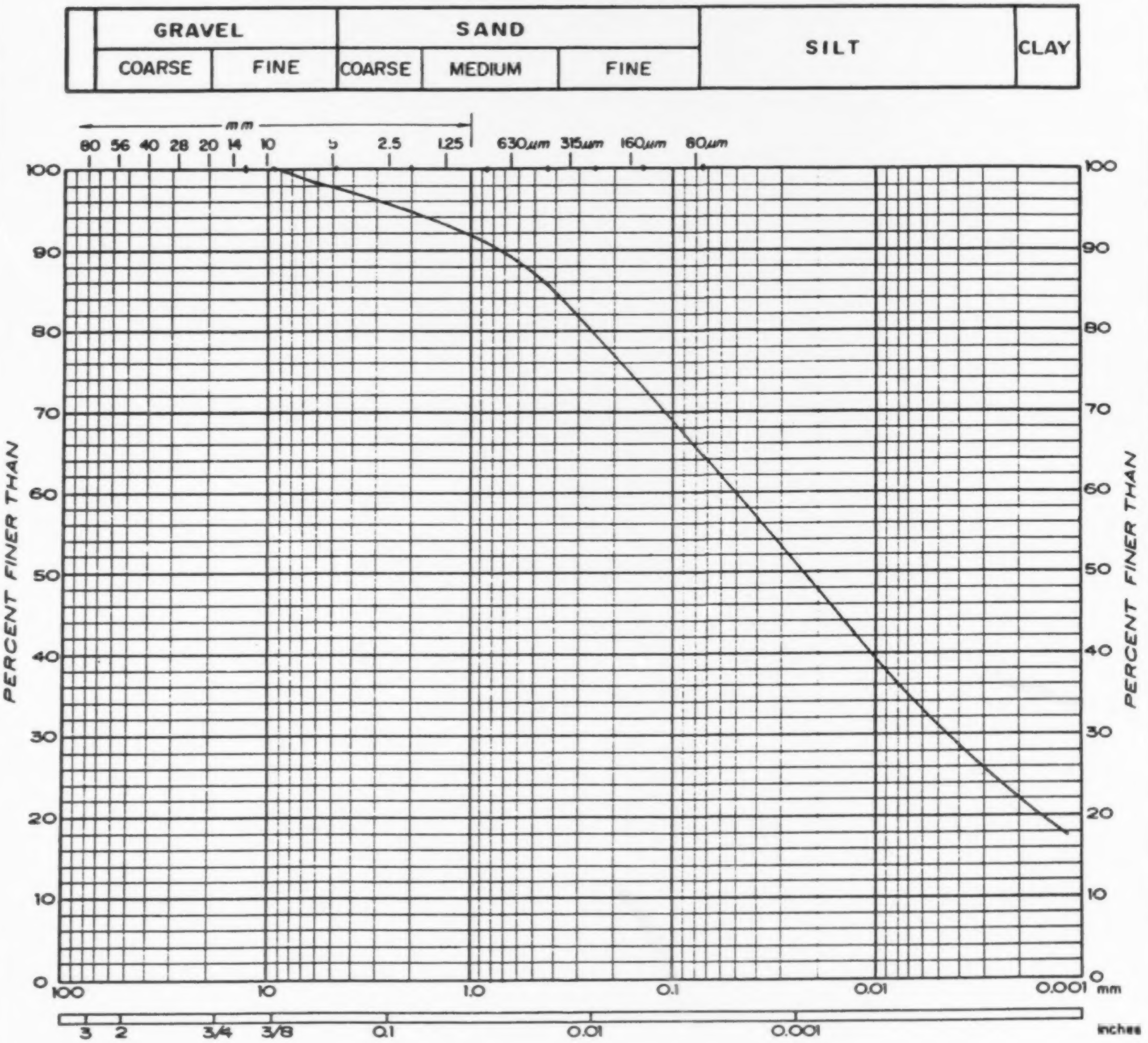
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P16 Depth 3.6m - 4.0m

DRAWING NO.
S84-1746-54



REMARKS: CLAY TILL - moist, hard, medium plastic, grey, oxide fracture planes

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

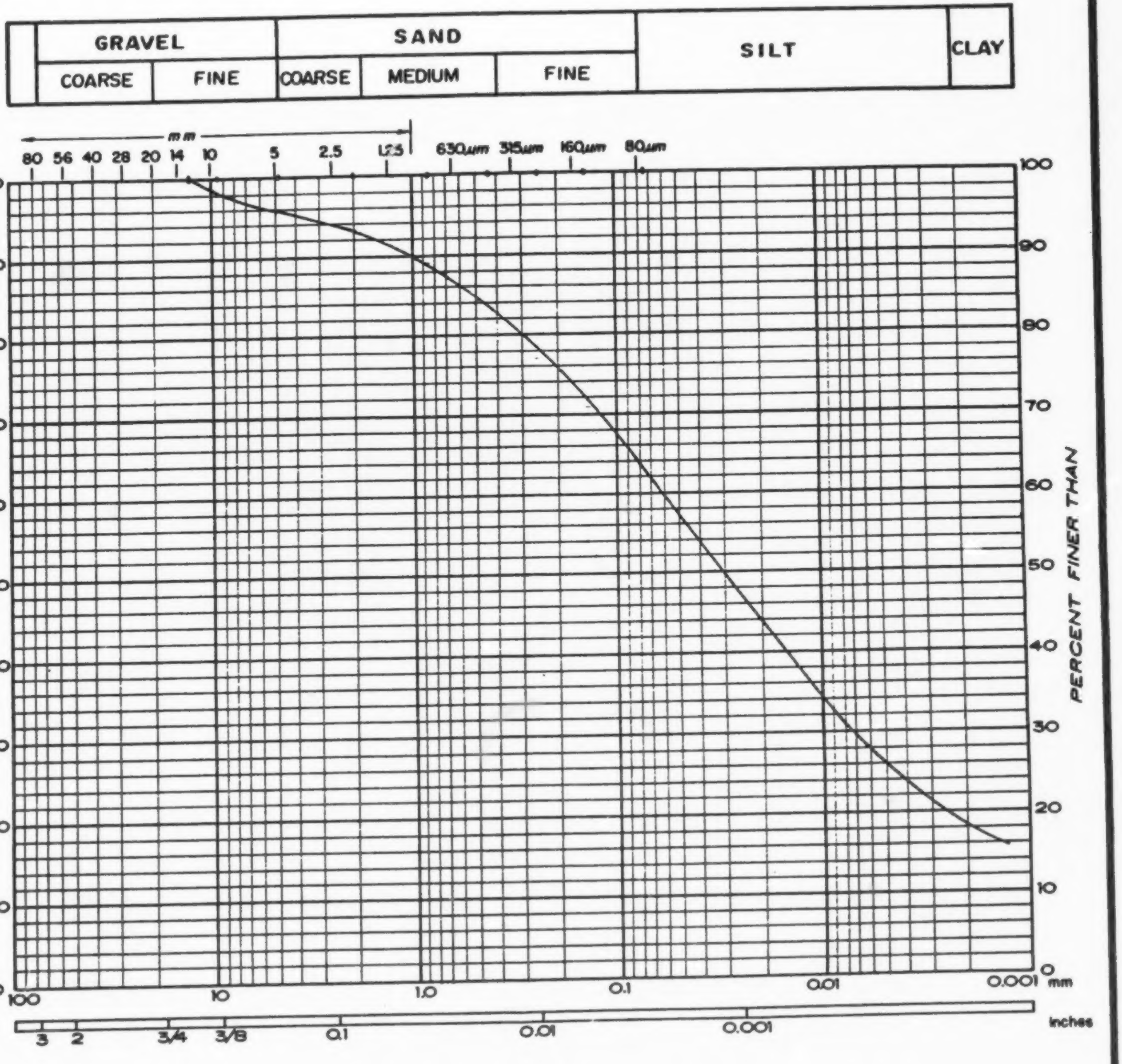
Tails Pile Instrumentation

PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P17 Depth 10.1m-11.6m

DRAWING NO.: S84-1746-55



REMARKS: *CLAY TILL - moist, hard, medium plastic, grey, fissures.*

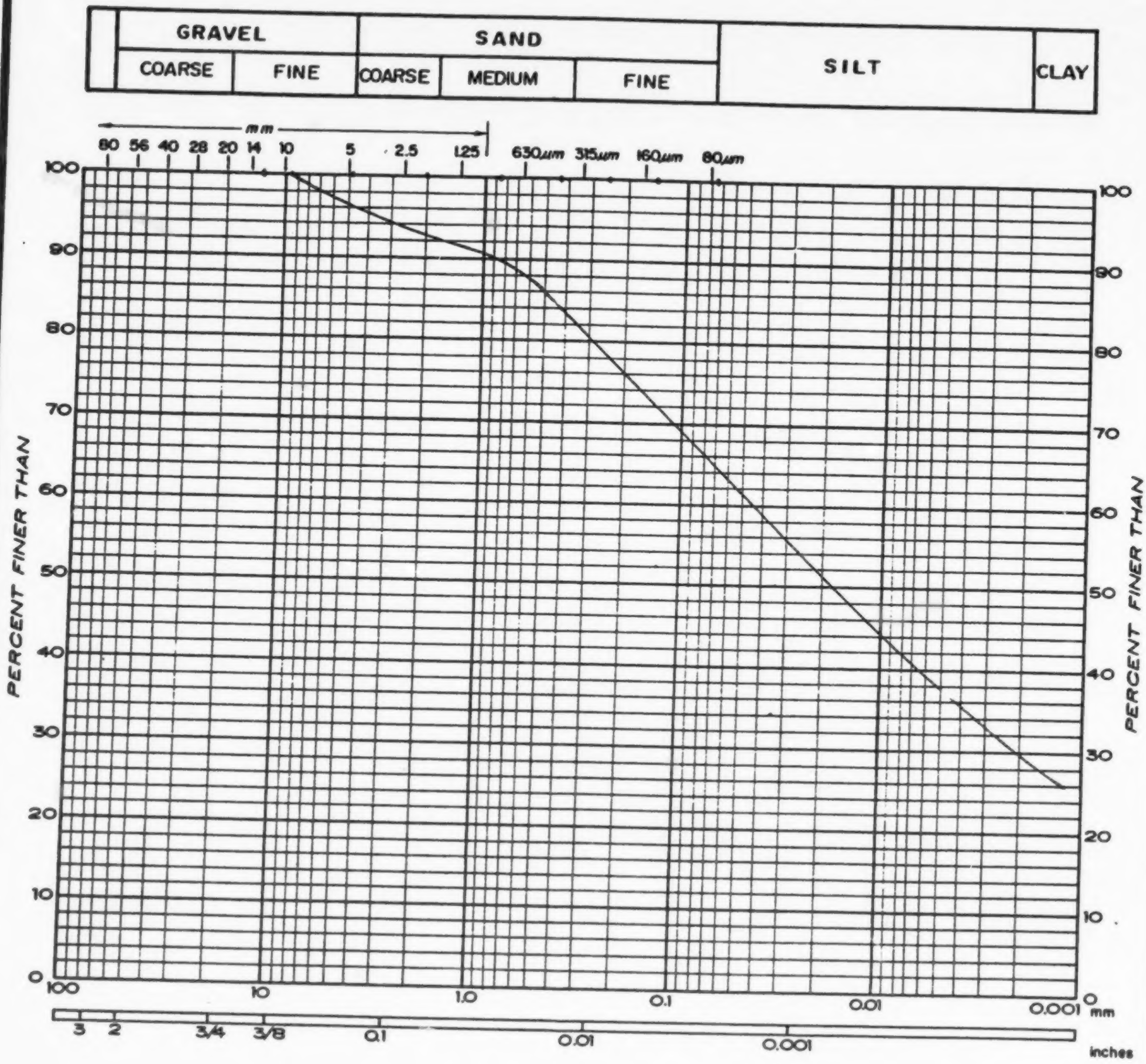
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. *P18* Depth *12.6m-13.0*

DRAWING NO: S84-1746-56



REMARKS: CLAY TILL - moist, hard, medium plastic, grey, fissures, shale chips

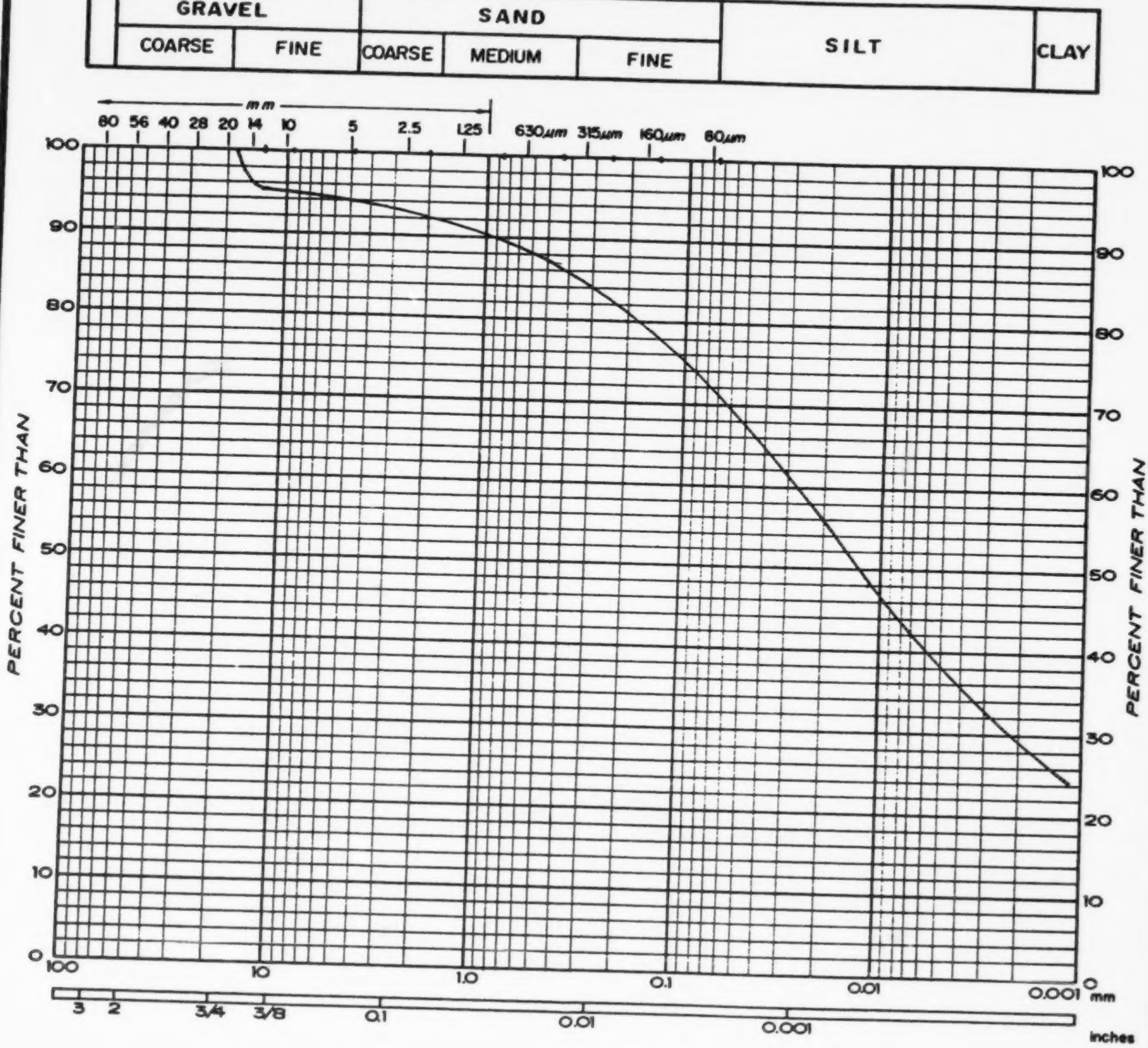
BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P19 Depth 25.5-25.6m

DRAWING NO: S84-1746-57



REMARKS: *CLAY TILL - moist, hard, medium plastic, grey, shale chips.*

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

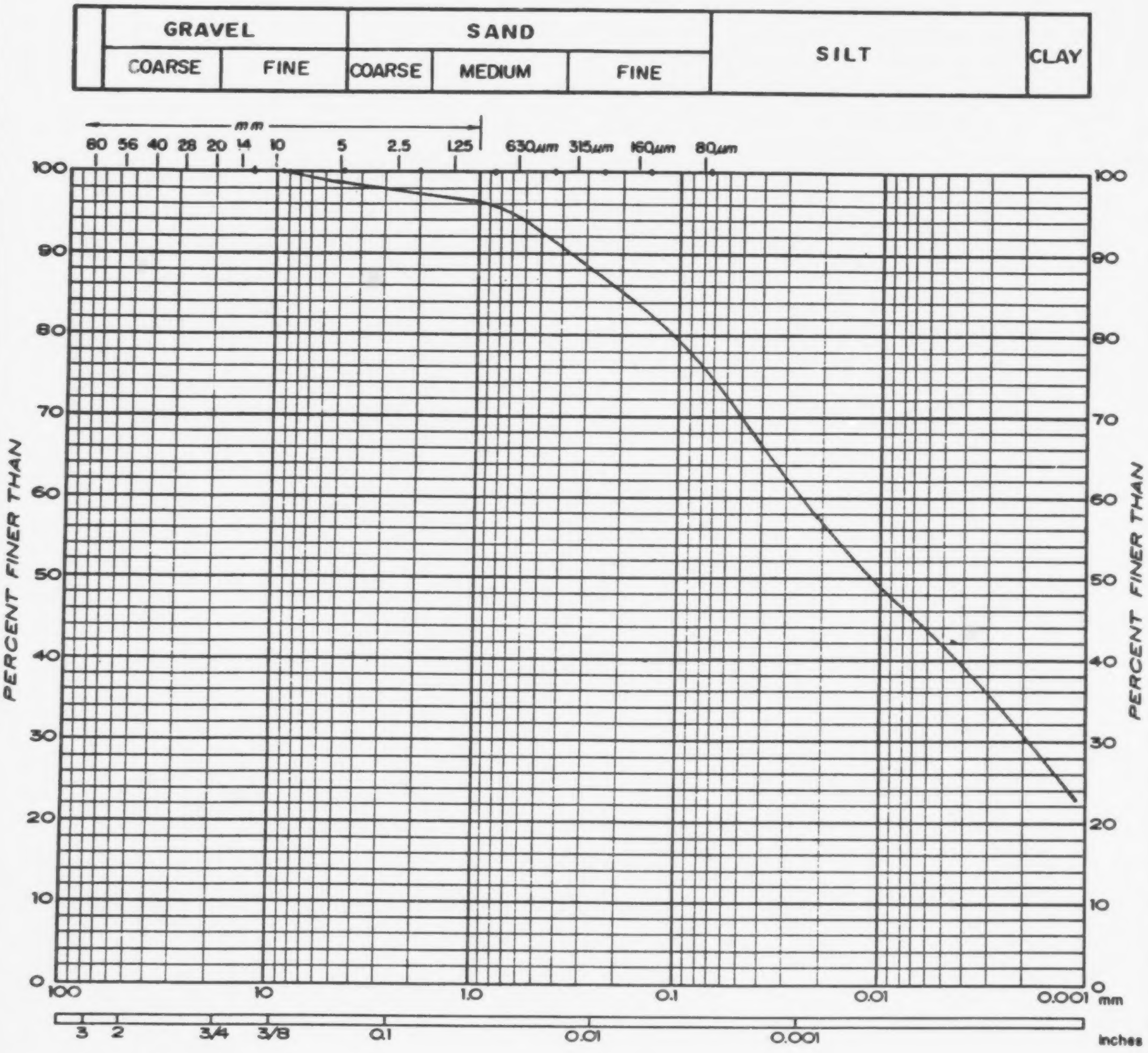
Tails Pile Instrumentation

PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. *P20* Depth *47.8-48.1m*

DRAWING NO: S84-1746-58



REMARKS : CLAY TILL - moist, hard, medium plastic, grey, shale chips

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

Tails Pile Instrumentation
PCS LANIGAN

GRAIN SIZE DISTRIBUTION

Test Hole No. P21 Depth 62.1-62.2m

DRAWING NO: S84-1746-59

APPENDIX 6

Manufacturer's Information

APPENDIX 6

Manufacturer's Information

Shipping Lists of Supplied Instrumentation

Instruction Manual Pore Pressure Indicator

Instruction Manual Liquid Settlement Transducer

Settlement Transducer Calibrations

SINCA UNIT #5 — 11300 RIVER ROAD
RICHMOND, B.C., CANADA V6X 1Z5
SLOPE INDICATOR CANADA LIMITED

INVOICE

INVOICE NO. 201720

INVOICE DATE November 27, 1984

SOLD TO
B.B.T. GEOTECHNICAL CONSULTANTS LTD.
221 Jessop Avenue
Saskatoon, Saskatchewan
S7N 1Y3

SHIPPED TO
B.B.T.
--SAME--
Attn: George Bell

OUR ORDER NO.	YOUR ORDER NO.	SALESMAN	TERMS	SHIPPED VIA	PPD OR COLL
	4390	GAH	NET 30	Air Frt	X

ITEM	QUANTITY	DESCRIPTION	PRICE	AMOUNT
001	1 ea	51401101 Portable Pneumatic Indicator, 0.10% gauge, 0-300 PSI, S/N 1461		
002	1 ea	51401120 APC Option for above indicator with Special APC Shut-off		
		Project # S84-1747.		
		*Price less than originally quoted.		
		Past due balances subject to a service charge of 1.5% per month.		

sinca UNIT #5 — 11300 RIVER ROAD
RICHMOND, B.C., CANADA V6X 1Z5
SLOPE INDICATOR CANADA LIMITED

INVOICE

INVOICE NO. 201739

INVOICE DATE January 8, 1985

SOLD TO
BBT GEOTECHNICAL CONSULTANTS LTD.
221 Jessop Avenue
Saskatoon, Saskatchewan
S7N 1Y3

SHIPPED TO BBT GEOTECH.
--Same--

OUR ORDER NO.	YOUR ORDER NO.	SALESMAN	TERMS	SHIPPED VIA	PPD OR COLL
	PO # 4391	GAH	NET 30	Trk Frt	X

ITEM	QUANTITY	DESCRIPTION	PRICE	AMOUNT
001	16 ea	51417800 P/P Transducer, S/N 23050 - 23065		
002	32 ea	51405502 Quick Connect Plug - 1/8" Elbow		
003	36 ea	07100000 Nut/Ferrule Combo for 1/8"		
004	1388 ft	51404700 Nylon Triple Tubing, 2 ea 1/8", 1 ea 3/16" Cut @ 37, 46, 50, 60, 70, 80, 92, 115, 138, 181, 37, 46, 60, 80, 115, & 181 feet.		
005	19 ea	51401703 Splice Kit for Triple Tubing		
006	1 ea	51417100 Pneumatic Terminal Pipe - 20 position plus 1		
007	20 ea	51100100 3.34" O.D. x 10 ft. long ABS Plastic Inclinometer Casing		
008	20 ea	51100200 3.34" O.D. ABS Plastic Coupling		
009	4 ea	51100500 3.34" ABS Protective Cap		

Past due balances subject to a service charge of 1.5% per month.

SINCA UNIT #5 — 11300 RIVER ROAD
RICHMOND, B.C., CANADA V6X 1Z5
SLOPE INDICATOR CANADA LIMITED

INVOICE

INVOICE NO. 201740

INVOICE DATE January 8, 1985

SOLD TO
BBT GEOTECHNICAL CONSULTANTS LTD.
221 Jessop Avenue
Saskatoon, Saskatchewan
S7N 1Y3

SHIPPED TO BBT GEOTECH.
--Same--

OUR ORDER NO.	YOUR ORDER NO.	SALESMAN	TERMS	SHIPPED VIA	PPD OR COLL
	PO # 4391	GAH	NET 30	Trk Frt	X

ITEM	QUANTITY	DESCRIPTION
001	1 ea	51417800 P/P Transducer S/N 23066
002	325 ft	51404700 Nylon Triple Tubing, 2 ea 1/8", 1 ea 3/16"
003	2 ea	51405502 Quick Connect Plug, 1/8" Elbow

(Above items comprise replacement piezometer for one damaged in installation.)

[BBT Project # S84-1747.]

Past due balances subject to a service charge of 1.5% per month.

sinca UNIT #5 — 11300 RIVER ROAD
RICHMOND, B.C., CANADA V6X 1Z5
SLOPE INDICATOR CANADA LIMITED

INVOICE

INVOICE NO. 201760

INVOICE DATE February 27, 1985

SOLD TO
BBT GEOTECHNICAL CONSULTANTS
221 Jessop Avenue
Saskatoon, Saskatchewan
S7N 1Y3

SHIPPED TO BBT GEOTECH. CONSULT.
---Same---

OUR ORDER NO.	YOUR ORDER NO.	SALESMAN	TERMS	SHIPPED VIA	PPD OR COLL
	S84-1746	GAH	NET 30	Trk Frt	X

ITEM	QUANTITY	DESCRIPTION	PRICE	AMOUNT
001	18335 ft	51404700 Triple Nylon Tubing - 2 ea @ 1/8" & 1 @ 3/16", cut into 21 lengths as follows: 1 @ 1005 ft. 2 @ 960 ft 4 @ 1000 ft. 1 @ 630 ft. 3 @ 990 ft. 1 @ 640 ft. 2 @ 985 ft. 2 @ 645 ft. 1 @ 980 ft. 2 @ 650 ft. 1 @ 975 ft. 1 @ 655 ft.		
002	3 ea	51401703 3-Tube Splice Kit		
003	3 ea	51408300 Amplified Settlement Transducer w/o Reservoir		
004	3 ea	51405501 Quick Connector Plugs - 1/8"		
005	3 ea	51419500 Liquid Settlement Reservoir		
006	2630 ft	50705101 Electrical Cable & Tubing, 5 tubes - 3 tubes for Pneumatic & 2 tubes liquid filled, cut & attached to transducers as follows: 1 @ 645 ft. 1 @ 985 ft. 1 @ 1000 ft.		
007	2 ea	51416100 Liquid Reservoir Terminal Pipe (2 Transducer)		

Past due balances subject to a service charge of 1.5% per month.

instruction manual

PORE - PRESSURE INDICATOR

Model 51411-B

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SINCO
Slope Indicator Co.

INSTRUCTION MANUAL

PNEUMATIC PRESSURE INDICATOR

MODEL 51411-B

TABLE OF CONTENTS

	Page
INTRODUCTION	1
SPECIFICATIONS	2
FUNCTION OF CONTROLS AND COUPLINGS	3
Panel Labels	3
Accessories	3
OPERATION PRECAUTIONS	4
BASIC OPERATING PROCEDURES	5
TANK REFILLING	7
EMPTYING TANK	7

INSTRUCTION MANUAL

PNEUMATIC PRESSURE INDICATOR

MODEL 51411-B

INTRODUCTION

The 51411-B Pneumatic Pressure Indicator is a portable, multiple-range readout for field or laboratory use. It is operable with SINCO Pneumatic Transducers:

Models:	51401	Pore Pressure Transducer
	51471	Pore Pressure Transducer
	51479	1:1 Liquid Settlement Transducer
	51481	Pore Pressure Transducer
	51482	Total Pressure Cell
	51484	Pore Pressure Transducer

SINCO, Model 51483 (Amplified Liquid Settlement Transducer) can also be read if an Automatic Flow Controller is installed in the readout. This is indicated by the letters A.F.C. following the serial number.

For Transducer Operational Procedures with the readout, refer to the Piezometer Instruction Manual supplied with the instruments.

SPECIFICATIONS

Model	51411-B
Weight	26 pounds
Gas Source	Integral Tank
Gas Volume	84 cu. in.
Maximum Source Pressure	2,000 psi
Gas	N2 Nitrogen
Output Pressure Gauge	Std. 100 psi
Scale Length	32-inch, double sweep, circular scale
Accuracy	0.1% Full Scale
Sensitivity	0.01% Full Scale
Repeatability	0.02% Full Scale
Hysteresis	0.01% Full Scale
Thermal Compensation	-25° to +125°F Automatic
Zero Adjustment	Manual
Ranges 30 to 500 psi	Optional
Automatic Flow Control	Optional Flow Control

FUNCTION OF CONTROLS AND COUPLINGS

PANEL LABELS	FUNCTION
TANK INPUT	Coupling used to fill internal nitrogen tank.
TANK PRESSURE	Gauge indicating supply pressure in tank.
SUPPLY PRESSURE REGULATOR	Regulates supply pressure, clockwise to increase, counterclockwise to decrease.
SUPPLY PRESSURE	Gauge indicating regulated supply pressure.
VENT	Valve to vent supply or output pressure.
METERED SHUT-OFF	Shuts off metered flow from supply pressure.
METERED INPUT	Fine needle valve used to adjust metered flow.
FLOWMETER	Visually indicates rate of metered flow.
TRANSFER	Valve used to connect input circuit to output pressure circuit.
TRANSDUCER INPUT	Coupling used to connect metered supply pressure into transducer.
TRANSDUCER OUTPUT	Coupling used to connect transducer output pressure.
OUTPUT PRESSURE	Gauge used for measuring transducer pressure.
DIRECT INPUT	Coarse needle valve used when purging or flushing transducer.
AUTOMATIC FLOW CONTROL (AFC)	Automatically maintains flow rate setting on flowmeter.

ACCESSORIES

TANK REFILL HOSE	High pressure hose for filling internal nitrogen tank.
JUMPER HOSE	Used when connecting the indicator to a terminal pipe.
DUST CAPS	Protective covers on tubing and plugs.

OPERATION PRECAUTIONS

1. When making coupler connections be certain that male and female ends are clean.
2. Make certain coupler connections are locked into place by female retaining ring.
3. Do not over-tighten METERED INPUT valve or DIRECT INPUT valve.
4. Be aware of pointer location of OUTPUT PRESSURE gauge; over-pressurizing can damage gauge.
5. Operate readout in a level position to assure sensitivity and repeatability.
6. Do not open TRANSFER valve unless VENT valve is open.

BASIC OPERATING PROCEDURES

Checking Output Pressure Gauge Zero

1. With all valves in closed position, open VENT valve.
2. Open TRANSFER valve.
3. Adjust large knob at bottom of the OUTPUT PRESSURE gauge and set pointer on zero.
4. Close TRANSFER valve.

Venting

1. All valves being closed, open VENT valve to vent the input circuit.
2. Open TRANSFER valve to vent the output circuit.

Supply Pressure Adjustment

1. Open VENT valve.
2. Turn SUPPLY REGULATOR handle clockwise to increase pressure being indicated on SUPPLY PRESSURE gauge.
3. Turn handle counter-clockwise to lower supply pressure.

Flowrate Adjustment

1. Properly set supply pressure.
2. Open VENT valve.
3. Open METERED SHUT-OFF valve.
4. Adjust METERED INPUT valve to indicate required flow on the flowmeter. Automatic controller maintains flow setting.
5. Close METERED SHUT-OFF to stop flowrate.

Input Pressure Transfer

1. Open TRANSFER valve when measuring pressure in the input circuit.
2. Close TRANSFER valve when measuring pressure from the output circuit.
3. VENT valve must be in closed position.

Direct Input Pressure

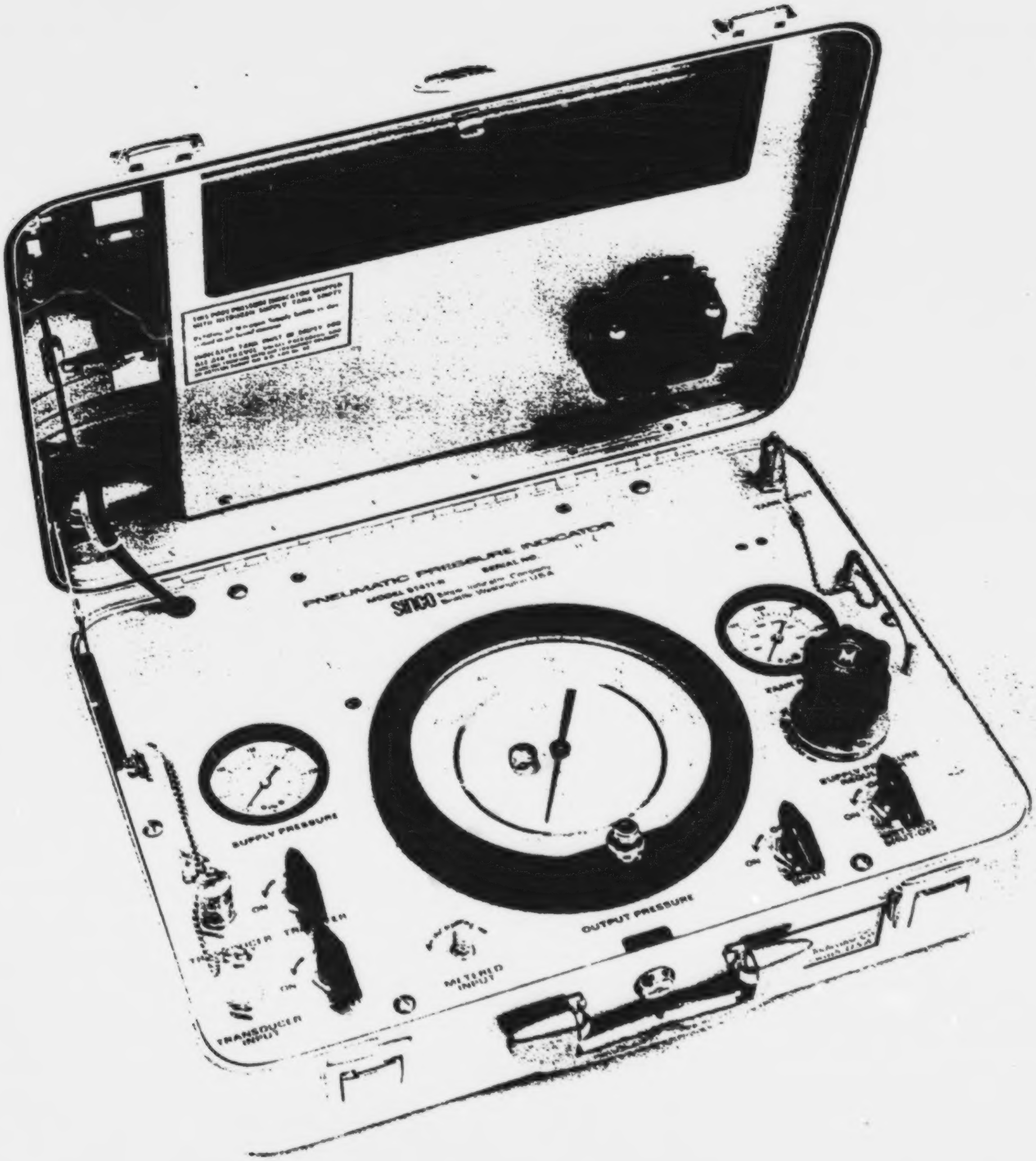
1. Set appropriate supply pressure.
2. Slowly open DIRECT INPUT valve to purge long pneumatic leads.
3. Maximum supply pressure can be set when flushing method is used.

TANK REFILLING

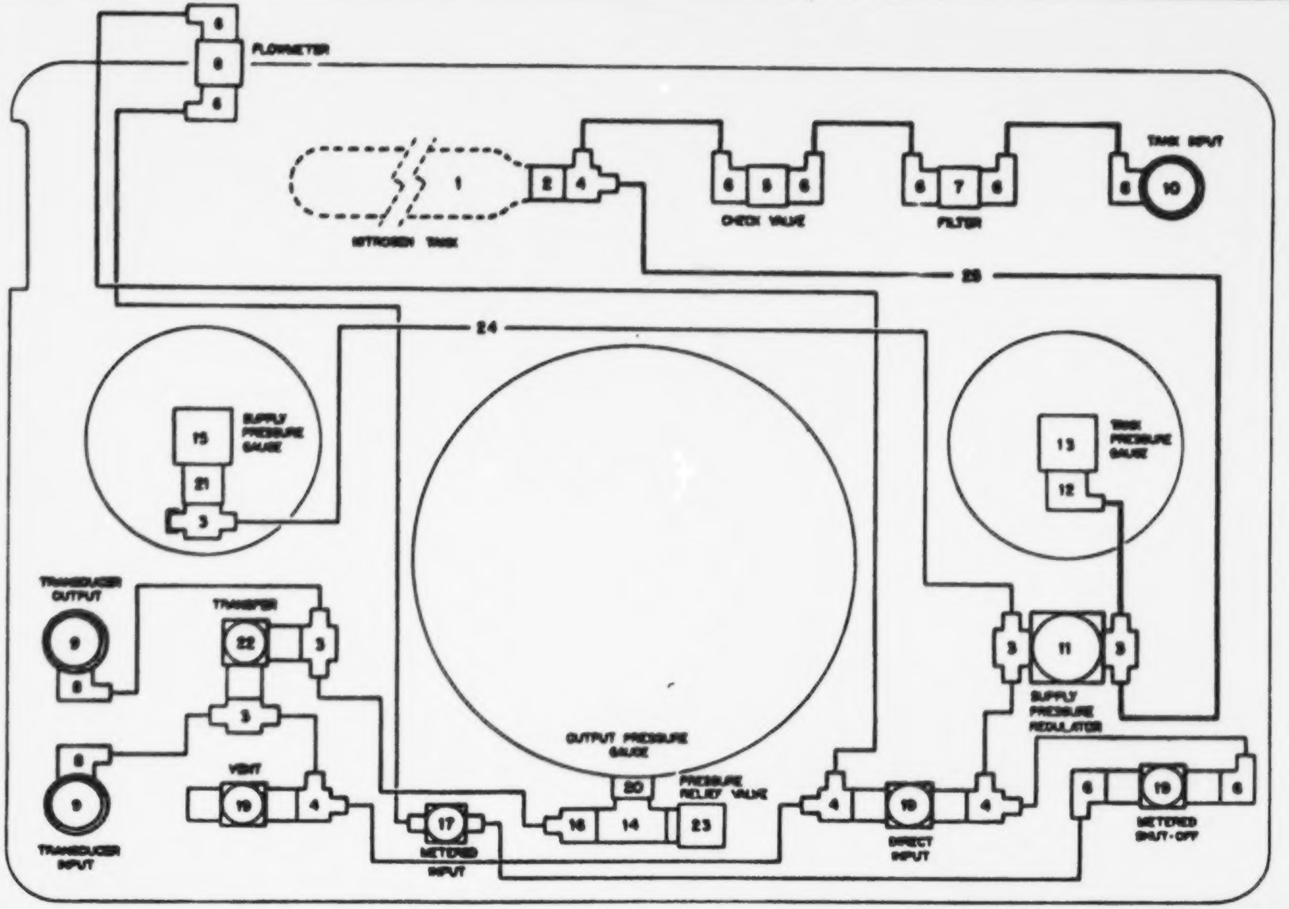
1. Remove dust caps on tank coupler & refill hose.
2. Connect refill hose to external tank and TANK INPUT coupler.
3. Open external tank valve slowly while observing TANK PRESSURE gauge.
4. Close external tank valve when TANK PRESSURE gauge STOPS rising or reaches 1800-2000 psi.
5. Release hose pressure by loosening connector at external tank.
6. Disconnect refill hose and replace dust caps.

EMPTYING TANK

1. Open VENT toggle valve.
2. Open DIRECT INPUT valve.
3. Turn SUPPLY REGULATOR clockwise until SUPPLY PRESSURE gauge reads 160 psi.
4. When TANK PRESSURE reads 100 psi close down SUPPLY REGULATOR by turning counter-clockwise.
5. Close DIRECT INPUT valve.
6. Close VENT toggle valve.


PNEUMATIC PRESSURE INDICATOR
SIMCO
SUPPLY PRESSURE
OUTPUT PRESSURE
TRANSDUCER INPUT
METERED INPUT
INPUT
ON

PNEUMATIC PRESSURE INDICATOR model 51411-B afc


FLOWMETER
1
NITROGEN TANK
2
4
CHECK VALVE
5
FILTER
7
TANK INPUT
10
25
24
SUPPLY PRESSURE GAUGE
15
21
3
TANK PRESSURE GAUGE
13
12
SUPPLY PRESSURE REGULATOR
11
TRANSDUCER OUTPUT
9
TRANSFER
22
TRANSDUCER INPUT
VENT
19
METERED INPUT
17
OUTPUT PRESSURE GAUGE
20
PRESSURE RELIEF VALVE
16
14
23
DIRECT INPUT
METERED SHUT-OFF

FLOW SCHEMATIC
PNEUMATIC PRESSURE INDICATOR
51411-B

SINCO SLOPE INDICATOR CO.
Seattle, Washington USA

REV	DATE 8-18-80	SHT 1	OF 1

FIG. 2

ARTS LIST

STRUMENT ESCRIPTION PNEUMATIC PRESSURE INDICATOR, P/N 51411-B

ICO PARTS ESIGNATION	QTY.	PART NAME AND DESCRIPTION	MATERIAL AND SPEC.	MANUFACTURER	MFG. PART NO.	PRICE UNIT	PRICE TOTAL	SUPPLIER
1	1	HIGH PRESSURE TANK		MARISON CO.	182			
2	1	BUSHING	BRASS ½ x 1/8PT	WEATHERHEAD	3220 x 8 x 2			
3	6	MALE BRANCH TEE	BRASS 1/8 x 1/8MPT	SWAGELOK, INC.	B-200-3TTM			
4	3	MALE RUN TEE	BRASS 1/8 x 1/8MPT	SWAGELOK, INC.	B-200-3TMT			
5	1	CHECK VALVE	BRASS 1/8 x 1/8MPT	HOKE, INC.	6113-F2B			
6	9	MALE ELBOW	BRASS 1/8 x 1/8MPT	SWAGELOK, INC.	B-200-2-2			
7	1	FILTER	BRASS 1/8FPT	HOKE, INC.	6317-F2B			
8	2	MALE ELBOW	BRASS 1/8 x ¼MPT	SWAGELOK, INC.	B-200-2-4			
9	2	MALE SELF-SEALING COUPLER	BRASS ¼FPT	HANSEN	B2-K16			
10	1	MALE SELF-SEALING COUPLER	STAINLESS STEEL 1/8FPT	HANSEN	SS1-K11			
11	1	SUPPLY PRESSURE REGULATOR	BRASS (B2PMSR) 1/8FPT	VARIFLOW	1R502			
12	1	FEMALE ELBOW	BRASS 1/8 x ¼FPT	SWAGELOK, INC.	B-200-8-4			
13	1	TANK PRESSURE GAUGE	2.5", ¼CB, 3000 PSI/kPa	MARSH	J6578			
14	1	TEE	BRASS 1/8PT	IMPERIAL EASTMAN	127-B x 02			
15	1	SUPPLY PRESSURE GAUGE	2.5", ¼CB, 400 PSI/kPa	MARSH	J6260			
16	1	MALE CONNECTOR	BRASS 1/8 x 1/8MPT	SWAGELOK, INC.	B-200-1-2			
17	1	METERING NEEDLE VALVE	BRASS 1/8TUBE	NUPRO	B-2SG			
18	1	FLOWMETER	GLASS VIAL 0.1-1.2SCFH	BROOKS	1350-50			
19	2	BALL VALVES (STRAIGHT)	BRASS 1/8FPT	WHITEY	B-42F2			
20	1	OUTPUT PRESSURE GAUGE	STAINLESS STEEL 0-200PSI	HEISE	CMM-6"			
21	1	REDUCING BUSHING	BRASS ¼ x 1/8PT	IMPERIAL EASTMAN	119-B			
22	2	BALL VALVE (ANGLE)	BRASS 1/8FPT	WHITEY	B-42F2-A			
23	1	PRESSURE RELIEF VALVE	BRASS 1/8MPT	NORGREN	16-004-005			
24	AS REQ.	LOW-PRESSURE TUBING	NYLON 1/8" OD	IMPERIAL EASTMAN	22-NF			

PREPARED BY HMc. DATE 12-4-80 PAGE 1 OF 2

SINCO Slope Indicator Company
Seattle, Washington U.S.A.

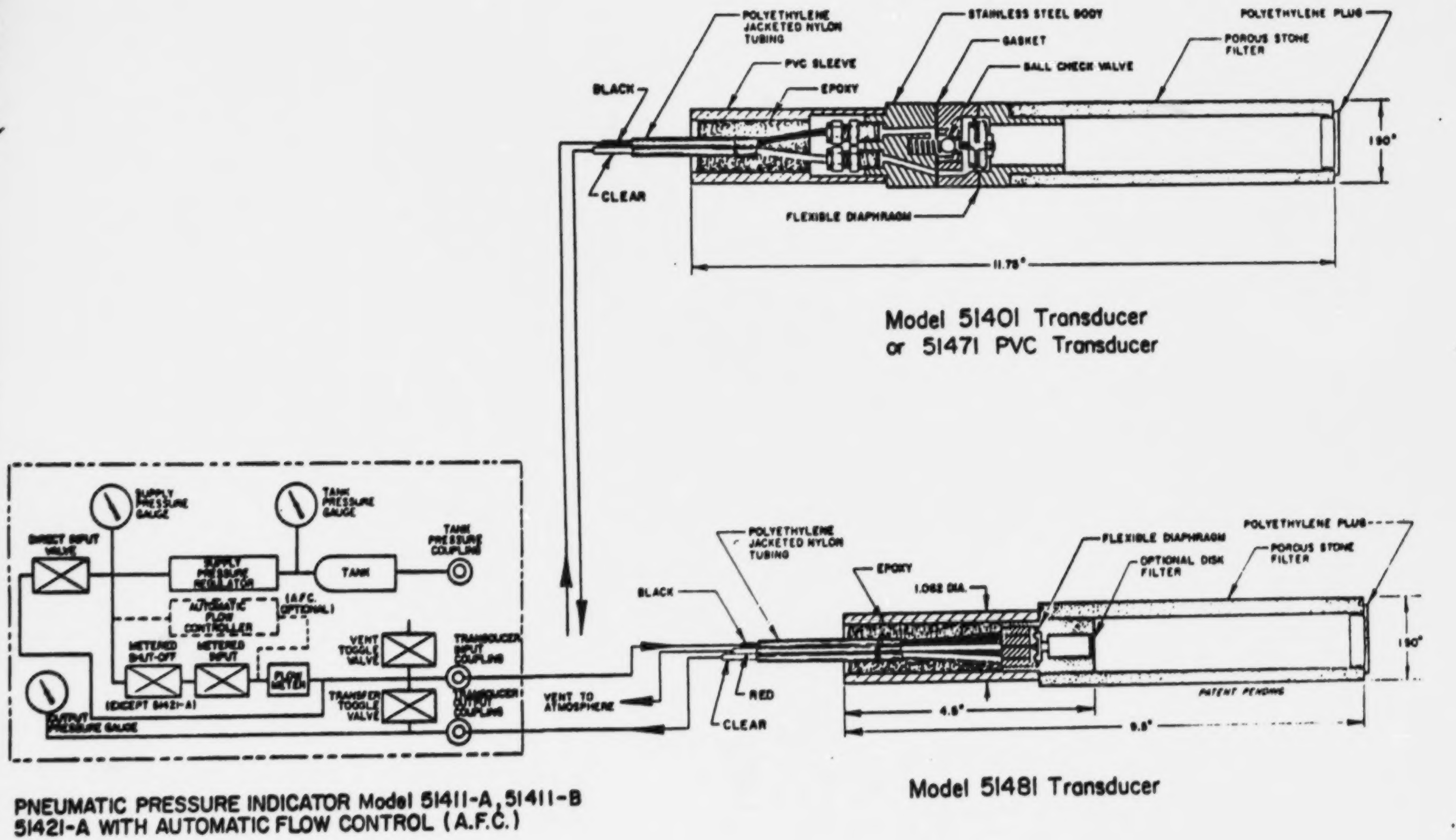
ARTS LIST

TRUMENT SCRIPTION PNEUMATIC PRESSURE INDICATOR, P/N 51411-B cont.

O PARTS IGNATION	QTY.	PART NAME AND DESCRIPTION	MATERIAL AND SPEC.	MANUFACTURER	MFG. PART NO.	PRICE		SUPPLIER
						UNIT	TOTAL	
25	AS REQ	, HI-PRESSURE TUBING	STAINLESS STEEL 1/8" OD		MILT. 8504			

PREPARED BY HMc. DATE 12-4-80 PAGE 2 OF 2

inco Slope Indicator Company
Seattle, Washington U.S.A.


POLYETHYLENE JACKETED NYLON TUBING
PVC SLEEVE
EPOXY
BLACK
CLEAR
STAINLESS STEEL BODY
GASKET
BALL CHECK VALVE
POROUS STONE FILTER
POLYETHYLENE PLUG
FLEXIBLE DIAPHRAGM
1.90"
11.75"
FLEXIBLE DIAPHRAGM
OPTIONAL DISK FILTER
POLYETHYLENE PLUG
POROUS STONE FILTER
EPOXY
1.062 DIA.
POLYETHYLENE JACKETED NYLON TUBING
BLACK
RED
CLEAR
VENT TO ATMOSPHERE
PATENT PENDING
4.5"
9.5"
1.90"
SUPPLY PRESSURE GAUGE
TANK PRESSURE GAUGE
DIRECT INPUT VALVE
SUPPLY PRESSURE REGULATOR
TANK
TANK PRESSURE COUPLING
AUTOMATIC FLOW CONTROLLER
(A.F.C. OPTIONAL)
METERED SHUT-OFF
METERED INPUT
FLOW METER
(EXCEPT 51421-A)
VENT TOGGLE VALVE
TRANSFER TOGGLE VALVE
TRANSDUCER INPUT COUPLING
TRANSDUCER OUTPUT COUPLING
OUTPUT PRESSURE GAUGE

Model 51401 Transducer
or 51471 PVC Transducer

Model 51481 Transducer

PNEUMATIC PRESSURE INDICATOR Model 51411-A, 51411-B
51421-A WITH AUTOMATIC FLOW CONTROL (A.F.C.)

PORE PRESSURE SYSTEMS WITH TRANSDUCERS

FIG. 3

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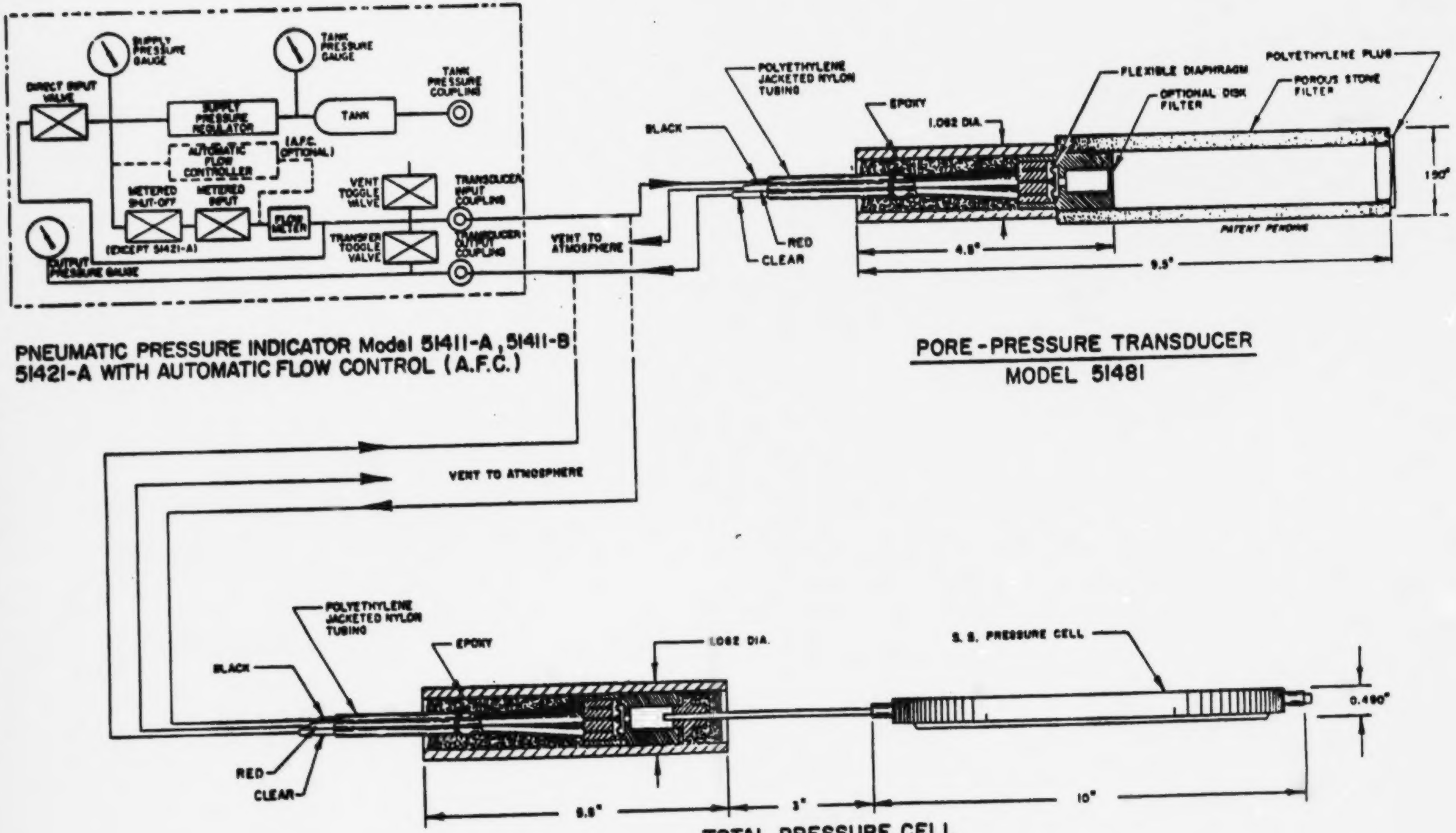
SUPPLY PRESSURE GAUGE
TANK PRESSURE GAUGE
DIRECT INPUT VALVE
SUPPLY PRESSURE REGULATOR
TANK
TANK PRESSURE COUPLING
AUTOMATIC FLOW CONTROLLER
(A.F.C. OPTIONAL)
METERED SHUT-OFF
METERED INPUT
FLOW METER
(EXCEPT 51421-A)
VENT TOGGLE VALVE
TRANSFER TOGGLE VALVE
TRANSDUCER INPUT COUPLING
TRANSDUCER OUTPUT COUPLING
OUTPUT PRESSURE GAUGE
VENT TO ATMOSPHERE
BLACK
POLYETHYLENE JACKETED NYLON TUBING
RED
CLEAR
EPOXY
1.062 DIA.
FLEXIBLE DIAPHRAGM
OPTIONAL DISK FILTER
POLYETHYLENE PLUG
POROUS STONE FILTER
1.50"
PATENT PENDING
4.8"
9.5"
VENT TO ATMOSPHERE
POLYETHYLENE JACKETED NYLON TUBING
EPOXY
1.062 DIA.
S. S. PRESSURE CELL
BLACK
RED
CLEAR
0.490"
9.8"
3"
10"

PNEUMATIC PRESSURE INDICATOR Model 51411-A, 51411-B 51421-A WITH AUTOMATIC FLOW CONTROL (A.F.C.)

PORE-PRESSURE TRANSDUCER
MODEL 51481

TOTAL PRESSURE CELL
MODEL 51482

CONSTANT-FLOW PRESSURE SYSTEMS

FIG. 4

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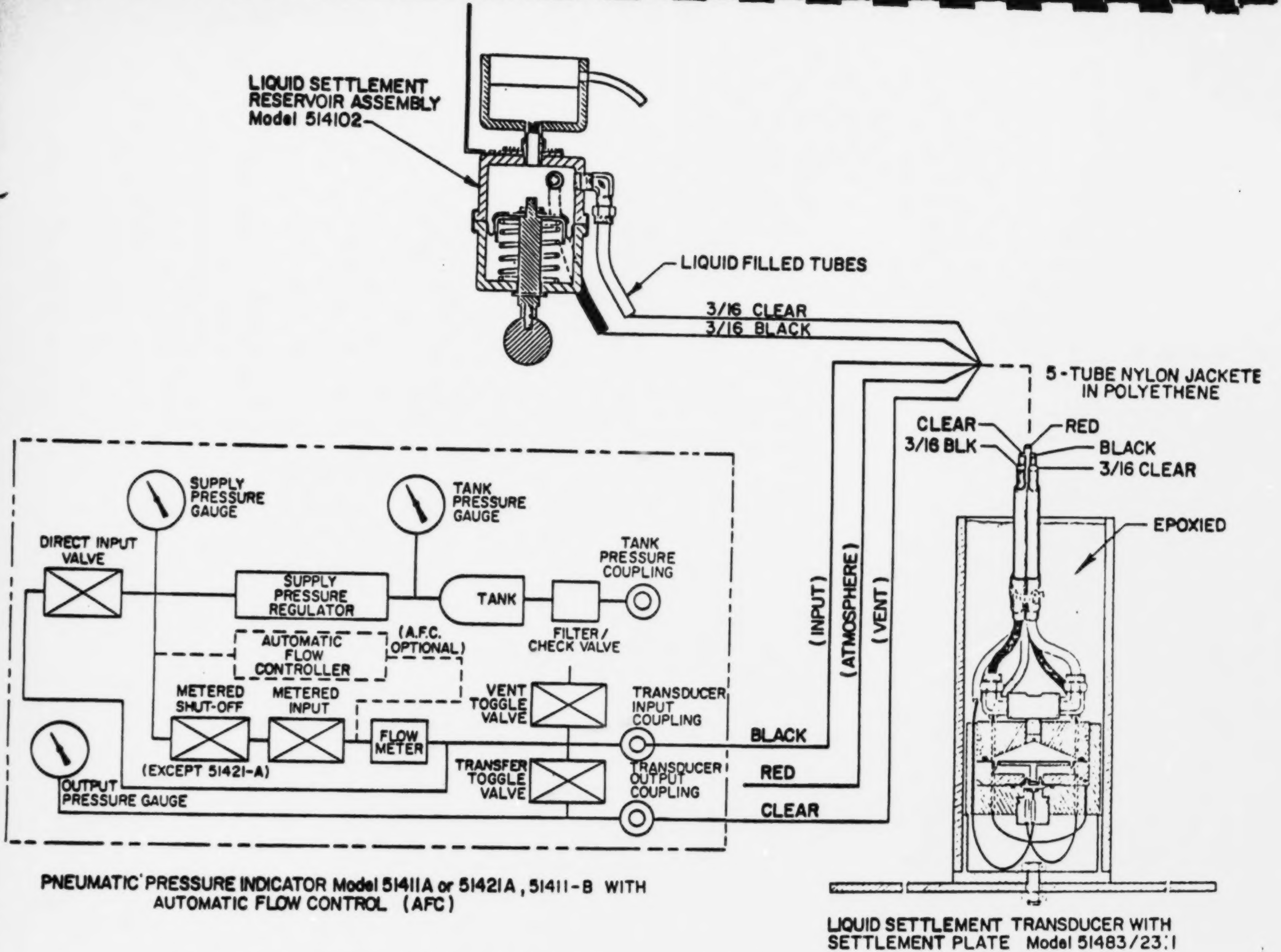
LIQUID SETTLEMENT RESERVOIR ASSEMBLY Model 514102
LIQUID FILLED TUBES
3/16 CLEAR
3/16 BLACK
5-TUBE NYLON JACKETE IN POLYETHENE
CLEAR
3/16 BLK
RED
BLACK
3/16 CLEAR
EPOXIED
(INPUT)
(ATMOSPHERE)
(VENT)
BLACK
RED
CLEAR
SUPPLY PRESSURE GAUGE
TANK PRESSURE GAUGE
DIRECT INPUT VALVE
SUPPLY PRESSURE REGULATOR
TANK
TANK PRESSURE COUPLING
FILTER / CHECK VALVE
AUTOMATIC FLOW CONTROLLER
(A.F.C. OPTIONAL)
METERED SHUT-OFF
METERED INPUT
FLOW METER
VENT TOGGLE VALVE
TRANSDUCER INPUT COUPLING
TRANSFER TOGGLE VALVE
TRANSDUCER OUTPUT COUPLING
(EXCEPT 51421-A)
OUTPUT PRESSURE GAUGE

PNEUMATIC PRESSURE INDICATOR Model 51411A or 51421A, 51411-B WITH AUTOMATIC FLOW CONTROL (AFC)

LIQUID SETTLEMENT TRANSDUCER WITH SETTLEMENT PLATE Model 51483/23:1

SETTLEMENT SYSTEM FLOW SCHEMATIC FIG. 5

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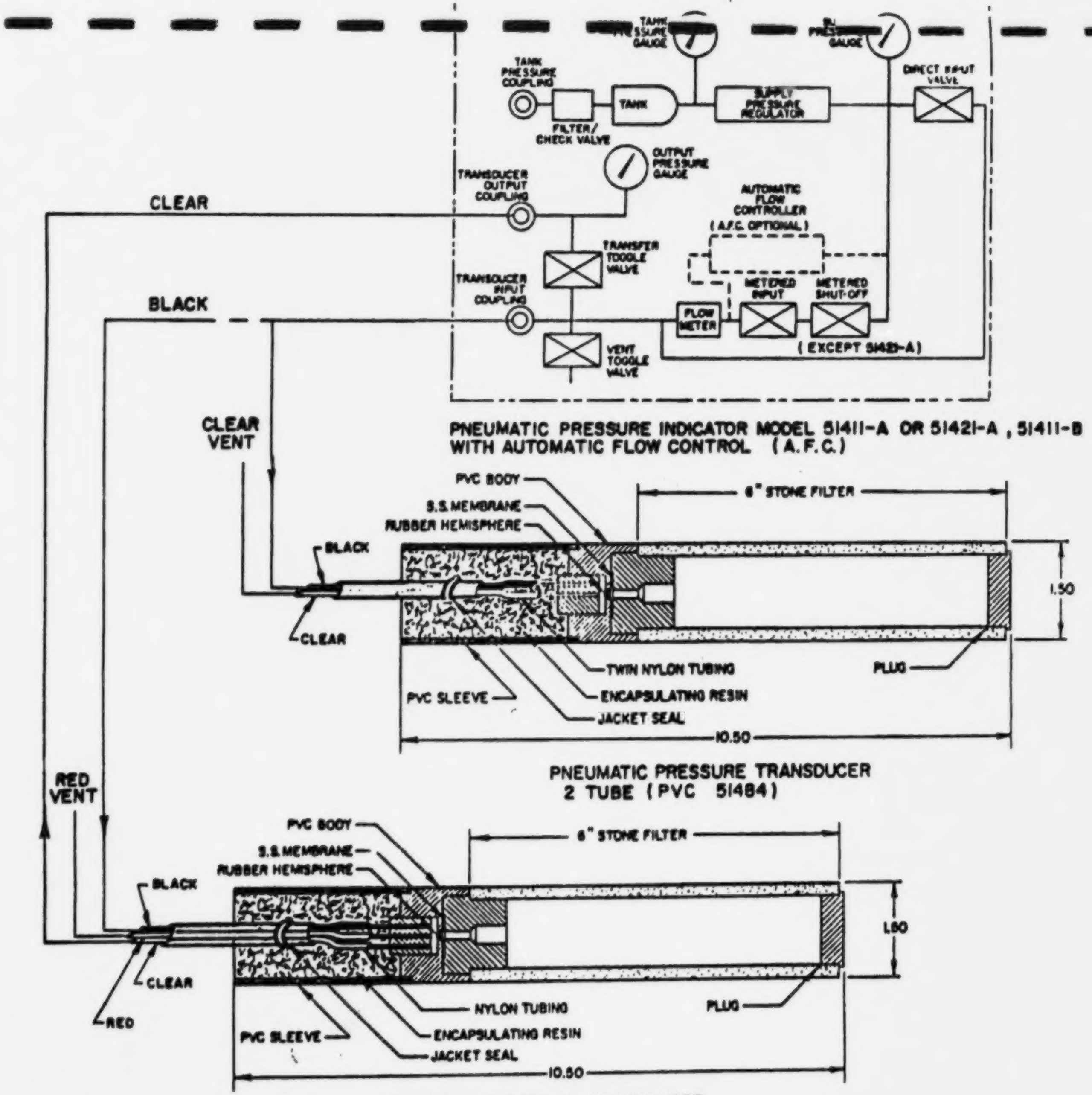

TANK PRESSURE GAUGE
IN PRESSURE GAUGE
TANK PRESSURE COUPLING
FILTER/ CHECK VALVE
TANK
SUPPLY PRESSURE REGULATOR
DIRECT INPUT VALVE
OUTPUT PRESSURE GAUGE
TRANSDUCER OUTPUT COUPLING
CLEAR
AUTOMATIC FLOW CONTROLLER
(A.F.C. OPTIONAL)
TRANSFER TOGGLE VALVE
TRANSDUCER INPUT COUPLING
BLACK
FLOW METER
METERED INPUT
METERED SHUT-OFF
(EXCEPT 51421-A)
VENT TOGGLE VALVE
CLEAR VENT
PVC BODY
S.S. MEMBRANE
RUBBER HEMISPHERE
BLACK
CLEAR
6" STONE FILTER
1.50
TWIN NYLON TUBING
PLUG
PVC SLEEVE
ENCAPSULATING RESIN
JACKET SEAL
10.50
RED VENT
PVC BODY
S.S. MEMBRANE
RUBBER HEMISPHERE
BLACK
CLEAR
RED
6" STONE FILTER
1.50
NYLON TUBING
PLUG
PVC SLEEVE
ENCAPSULATING RESIN
JACKET SEAL
10.50

PNEUMATIC PRESSURE INDICATOR MODEL 51411-A OR 51421-A , 51411-B
WITH AUTOMATIC FLOW CONTROL (A.F.C.)

PNEUMATIC PRESSURE TRANSDUCER
2 TUBE (PVC 51484)

PNEUMATIC PRESSURE TRANSDUCER
3 TUBE (PVC 51484)

FIG. 6

SINCO Slope Indicator Comp
Seattle, Washington U.S

instruction manual

LIQUID SETTLEMENT TRANSDUCER

Model 51483

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Slope Indicator Co.

Rev: 02-07-85 WP 0232B

INSTRUCTION MANUAL

LIQUID SETTLEMENT TRANSDUCER

Model 51483/20:1 Ratio

TABLE OF CONTENTS Page

1.0 GENERAL INFORMATION 01
  1.1 INTRODUCTION 01
  1.2 DESCRIPTION 01
  1.3 SPECIFICATIONS 03

2.0 INSTALLATION METHODS 04
  2.1 EXCAVATING AND TRENCHING PROCEDURES ... 04
  2.2 SETTLEMENT TRANSDUCER INSTALLATION ... 04
  2.3 RESERVOIR INSTALLATION 05
  2.4 PRE-TEST BEFORE BACKFILLING 06
  2.5 BACKFILLING AND COMPACTION 08

3.0 MEASUREMENT PREPARATIONS AND PRECAUTIONS ... 09
  3.1 PRECAUTIONS 09
  3.2 TUBING CONNECTIONS 09
  3.3 PNEUMATIC INDICATOR REQUIREMENTS 10

4.0 PRESSURE MEASUREMENT 11
  4.1 51483 PRESSURE MEASUREMENT WITH FIVE-TUBE TUBING CONFIGURATION 11
    4.1.1 Preparation 11
    4.1.2 Data Acquisition 12
    4.1.3 Shut-Down 13
  4.2 FIELD DATA 14

5.0 TROUBLESHOOTING 15
  5.1 PURGING 15
  5.2 DE-AIRING LIQUID LEADS 15

INSTRUCTION MANUAL

LIQUID SETTLEMENT TRANSDUCER

Model 51483/20:1 Ratio

1.0 GENERAL INFORMATION

1.1 INTRODUCTION

The Slope Indicator "LIQUID SETTLEMENT TRANSDUCER, Model 51483", is a pneumatic-hydraulic instrument system which can measure small settlements in construction areas inaccessible to standard optical surveying techniques. It is especially useful in measuring large changes in settlement at high liquid head differentials under earthen dams, land fills, and soft soils.

The transducer is a 23:1 ratio type that measures the weight of liquid directly from a fixed reservoir. This instrument is capable of continuous monitoring over extended periods of time.

1.2 DESCRIPTION

The Liquid Settlement System consists of three major components, none of which have any metal moving parts:

- **THE TRANSDUCER** or sensing unit is designed to provide a calibrated continuous reading and be installed at a point where settlement is to be measured.

- **THE RESERVOIR** and terminal support are installed at a stable location outside the construction area, or in an area where the relative elevation can be obtained by conventional survey measurements. (This reservoir is provided with a controlled reference overflow tube which functions as the datum elevation with respect to the vertical transducer movements.)

- **THE LIQUID AND PNEUMATIC CONNECTING TUBING** consists of 5 tubes protected by a polyethylene jacket. three 3/16" or 1/4" size tubes contain liquid to provide a hydrostatic head for the transducers; the two remaining tubes communicate the gas and air pressure needed to operate the transducer. The input tube (black) supplies a monitored, controlled flow of pressure while the output tube (clear) vents the excess pressure to balance the two flexible membranes within the transducer. The (red) tube controls the atmospheric chamber between the two balancing diaphragms.

Readings are made when a balance is achieved between the hydraulic head of the fluid and the metered gas pressure inside the transducer. The accuracy of the system is determined by the accuracy of the readout gauge and the repeatable flowrate selected for the indicator. Example: Using a 0-60 psi pressure gauge at 0.1 percent of full scale accuracy, a settlement sensitivity of ±0.06 psi (±1.67 inch H_2O) change of liquid can be detected on the pressure gauge.

A total settlement of 10-feet (120 inches) can be measured. Accuracy and repeatability of readings are on the order of ±0.1 inch. Sufficient slack should be provided to allow for settlement of the transducer without stretching or breaking the tubing. The tubing is usually buried in a trench for protection. A couple of hundred feet of distance can be planned between the reservoir and transducer. Longer lengths (example 400-feet) will require more time to read because the liquid displacement characteristics of the transducer will take more time to balance.

1.3 SPECIFICATIONS

Dimensions: 3.34" outside diameter by 8" high

Weight: 3 to 5 lbs

Material:

Sensor & Amplifier Body - PVC cast in epoxy resin
Diaphragms - Nirtile rubber (Buna-N)
Reservoir - PVC

Sensitivity: ±0.06 psi of settlement

Range: 30 to 120 inches of settlement or heave

Accuracy and Repeatability: ±0.1 inch over the total range (related to gauge range and sensitivity)

Amplification: Approximately 23 to 1 or 10 psi per foot

Tubing: 4 or 5-tube, .040" wall, polyethylene bundle with waterproof jacket: 2 hydraulic tubes, 3/16" or 1/4"; 2 pneumatic, or 3 pneumatic, 3/16" or 1/8". (Optional tubing configurations available.)

Liquid: 100% Ethylene Glycol, or 50/50 Ethylene Glycol and with distilled water (special mixes available upon request).

Maximum Pneumatic Working Pressure: 200 psi

Pneumatic Indicator Type: Requires automatic flow control.

Maximum Tubing Length: 400 feet

Temperature Effect: 0.02 to 0.05 psi/degree centigrade.

2.0 INSTALLATION METHODS

2.1 EXCAVATING AND TRENCHING PROCEDURES

The location of the Liquid Settlement Transducer, trench line, and reservoir should be staked out by surveyors prior to installation of the system. The elevation of the transducer should be marked on the transducer reference stake. Excavation for the transducer should be 12 to 16 inches deeper than the bottom of the trench, with the bottom of the excavation being approximately 24 x 24 inches square, as shown in Fig. 3., to accommodate the 18" x 18" square settlement plate.

Trenching from the transducer point towards the terminal location can now proceed prior to installing the transducer and tubing. Sharp stones and rocks in the trench should be removed and a base of sand placed in the trench to prevent abrasions to the tubing. For most field installations, a trench depth of 18 to 24 inches and a width of 6 to 12 inches is sufficient for a double run of instrument tubing. Allow tubing to snake back and forth in the trench. An extra two percent length of tubing should be added to the straight line distance for proper slack.

Backfill the trench with approximately 3 to 5 inches of moist sand or selected fine graded material to provide bedding and continuous tubing support. Remainder of the trench is backfilled after the transducer is pre-tested and the reservoir is permanently attached.

2.2 SETTLEMENT TRANSDUCER INSTALLATION

To prevent tipping or rotation of the sensor after installation, a settlement plate, 18 inches square, should be attached to the bottom of the transducer. Pack 3 to 5 inches of moist sand or fine graded material into the bottom of the excavation and lower the transducer by the edges of the settlement plate. The transducer is then leveled as it is worked into place. The elevation of the plate is surveyed so that it can be referenced later to the reservoir elevation. Allow extra slack for any unexpected settlement by making a loop with the instrument tubing above the transducer. The tubing is then zig-zagged in the trench every 5 to 8 feet and covered with sand or fine graded material 3 to 5 inches thick taking care to remove sharp stones from the trench and avoiding sharp bends that may damage the tubing. Prior to backfilling around the transducer and tubing, the reservoir should be installed and a test reading taken.

2.3 RESERVOIR INSTALLATION

The reservoir terminal point should be located at a accessible place outside the work area on stable ground. A rigid support like a wooden or metal post is secured into the ground and the reservoir fastened so that it becomes the highest point in elevation, above the settlement transducer. The reservoir is then temporarily fastened to this support, so it can be raised or lowered to adjust for the minimum head of liquid required which is correlated to the Indicator's output pressure gauge range. Loop the excess instrument tubing back and forth into the trench allowing enough slack tubing to reach the reservoir terminal support.

Prior to the final backfilling of the trench, readings of the transducer should be taken to satisfy the operation of the settlement system.

NOTE: Elevations of the settlement plate and reservoir may be surveyed to determine initial datum data.

Temporarily mount the reservoir to the support with screws or tape. Remove the reservoir cover and install the overflow tube in the side hole.

Add liquid to the reservoir before coupling the liquid connections.

Fill the female sockets with liquid before coupling them to the reservoir, this minimizes the introduction of air into the system. Air bubbles can be removed by squeezing the soft clear tubes just below the female sockets after the connections are properly coupled together at the bottom of the reservoir.

CAUTION: The liquid leads of the Liquid Settlement Transducer are under 20 psi pressure. Care must be taken not to get liquid in the eyes when making connections to the reservoir.

Before taking a set of readings, overfill the reservoir and collect the excess liquid from the reference overflow tube by removing its plastic cap.

2.4 PRE-TESTS BEFORE BACKFILLING

It is recommended that a measurement be taken before completion of the backfill to assure that the system is operating properly. This procedure will also help determine the minimum head differential so that the reservoir can be permanently secured.

Prepare the Liquid Settlement system and portable indicator for taking measurements by following the MEASUREMENT INSTRUCTIONS outlined in this manual.

- Take an initial reading and record the data.

- Calculate the liquid head differential (vertical distance between sensor and reservoir) using the sensitivity and zero offest from settlement calibration data supplied with the transducer.

  Minimum head differential can be computed by subtracting the zero offset from your indicated reading and then dividing it by the sensitivity. The sensitivity is equal to the change in the transducer's OUTPUT (Calibration) reading divided by the change in the INPUT (calibrated liquid head).

  Calculated Head = (Reading - Zero Offset)/Sensitivity

  Sensor should be placed at a the minimum liquid head differential of 1 meter (3 feet), or the smallest calculated liquid head that the sensor can still operate.

- Once the minimum head differential has been established, move reservoir accordingly.

- Move reservoir up 10 to 12 inches (254 mm or 305 mm).

- Record the pressure reading.

- Calculate the difference between the two readings.

- Use the sensitivity data to compare the readings against the calculated difference for proper transducer operation.

- Restore reservoir back to the minimum head differential position to verify system repeatability.

2.5 BACKFILLING AND COMPACTION

The backfilling and compaction requirements should conform to the engineer's specification, or as outlined in the project specifications.

3.0 MEASUREMENT PREPARATIONS AND PRECAUTIONS

3.1 PRECAUTIONS

The transducer's liquid leads are filled with a de-aired anti-freeze mixture of Glycol and distilled water*. Should air pockets occur in the liquid leads, they must be removed by a special de-airing method. See "Trouble-shooting" on de-airing liquid leads.

A minimum of 3 feet of liquid head (approx. 30 psi) should be the lowest reading on the indicator when installing the settlement transducer. Friction caused by the diaphragm will begin to influence the operation of the transducer at this lower head of liquid.

Dust caps are provided to keep the vent leads and quick connectors from contamination and must be removed to operate the settlement transducer.

3.2 TUBING CONNECTIONS

The transducer's self-sealing couplers and the indicator's output receptacles must be clean before connections are made. Should oil or grease be used on these couplings for lubrication, all excess lubricant residue must be wiped clean.

To connect the transducer quick connector plugs to the Pneumatic Indicator, depress the outside retainer ring of the input or output receptacle and insert the plug. This outside retainer ring must return to its original position to correctly lock the couplers together.

---

*Mixture may vary upon special job request.

The self-sealing couplers have a safe working pressure well above the maximum pressure ranges of the pressure indicator. If leaking occurs at this connection, the O-ring in the receptacle should be checked for nicks and abrasions.

3.3 PNEUMATIC INDICATOR REQUIREMENTS

Liquid Settlement Transducers require a constant source of dry nitrogen gas regulated at a fixed pressure that is metered at a controlled flow. The pneumatic indicator must be capable of the above pressure regulations including the functional operations of venting, direct flow control, and accurate automatic flow metering.

The range and accuracy of the indicator's output pressure gauge will limit both the sensitivity and the total settlement capability of the system. Standard pressure ranges are available to satisfy most project applications.

4.0 PRESSURE MEASUREMENT

4.1 51483 PRESSURE MEASUREMENT WITH FIVE-TUBE TUBING CONFIGURATION

The following instructions outline the proper operating procedures for the five tube Model 51483 Settlement Transducer.

NOTE: Words in capital letters denote titles of the controls on the indicator panels, or items of importance.

4.1.1 Preparation

The following instructions pertain to the set-up and connection of the Model 51483 Settlement Transducer to the pneumatic indicator prior to taking a pressure measurement.

- CLOSE all the valves on the Pneumatic Pressure Indicator, after checking the zero setting on the OUTPUT PRESSURE gauge. Refer to Pneumatic Indicator Instruction Manual for zero setting procedures.
- OPEN the VENT valve.
- ADJUST the SUPPLY PRESSURE to approximately 140 psi by turning the SUPPLY REGULATOR handle CLOCKWISE.

NOTE: Lower supply pressures may be set to lessen the stresses on the automatic flow controller. A supply pressure of 20 psi abaove your highest transducer reading is sufficient.

- REMOVE all the protective dust caps from the pneumatic tubes and couplers (BLACK CLEAR and RED).

- WIPE CLEAN all connecting couplers before connecting to the Pneumatic Indicator.

- CONNECT the pneumatic INPUT coupler (BLACK tube to the INPUT coupler and the CLEAR and RED tube are VENTED TO ATMOSPHERE).

IMPORTANT: DO NOT CLOSE VENT VALVE unless tubing connections are ready.

- With the transfer valve ON and the vent valve OFF, adjust the A.F.C. METERED INPUT valve to indicate 0.1 SCFH on the flowmeter. This rate is very slow and is increased by selecting MANUAL METERED SUPPLY, and adjusting the metered input needle valve to indicate a flowmeter rate between 0.2 to 0.3 SCFH (Standard Cubic Feet per Hour).

4.1.2 Data Acquisition

With the indicator properly prepared, the following procedures will apply.

- When the pointer of the output pressure gauge stops rising and falls back slightly, then MANUAL METERED SUPPLY OFF.

The measurement on the output pressure gauge will slowly stabilize to the settlement reading. Allow output pointer to stabilize, tap gauge lightly.

- VERIFY the flow rate and adjust, if necessary, the flow through the flowmeter as outlined in the Pneumatic Indicator Instruction Manual.
- Record and repeat measurement.
- Repeat the above operations to verify the settlement reading.

REMEMBER: Follow the proper operating instruction of the indicator to help achieve the full accuracy of the system.

- RECORD the measurement reading once the output pressure gauge stabilizes.

4.1.3 SHUT DOWN

- Disconnect the pneumatic tube coupler and replace the protective caps. DO NOT vent the pneumatic tube, as the gas retained in the tubing and transducer helps guard against moisture and contamination entering the system. The gas retained also aids in faster pressurization of the transducer on the next recording date.

- OPEN the VENT valve to ZERO the OUTPUT PRESSURE gauge.

- CLOSE the SUPPLY PRESSURE REGULATOR by turning the handle COUNTER-CLOCKWISE.

- CLOSE ALL valves EXCEPT the METERING valves.

4.2 FIELD DATA

Settlement transducer calibration data is supplied with each Liquid Settlement Transducer. this data shows the range of calibration, sensitivity, zero offset, and the formula for computing calculated Liquid Head.

The method of recording and computing the settlement field data will no doubt vary with each construction project. The basic recording method would be to compute the trend of settlement between periodic measurements rather than the changes in elevations.

Initial readings are taken and referenced to the reservoir elevation prior to construction in the area of the Settlement Transducer. The elevation of the reservoir should be checked periodically for changes if the settlement readings vary excessively with respect to the computed settlement.

To compute settlements: subtract the base reading (initial) from the periodic readings and record these differences. A graphic plot of these differences will illustrate the trend of settlement.

5.0 TROUBLESHOOTING

5.1 PURGING

Purging the transducer with a high flow of gas pressure will be necessary when moisture or foreign particles contaminate the settlement system.

- REMOVE the protective dust caps and connect the transducer input lead into the input receptacle on the indicator.

- REMOVE the transducer output coupler from the instrument lead.

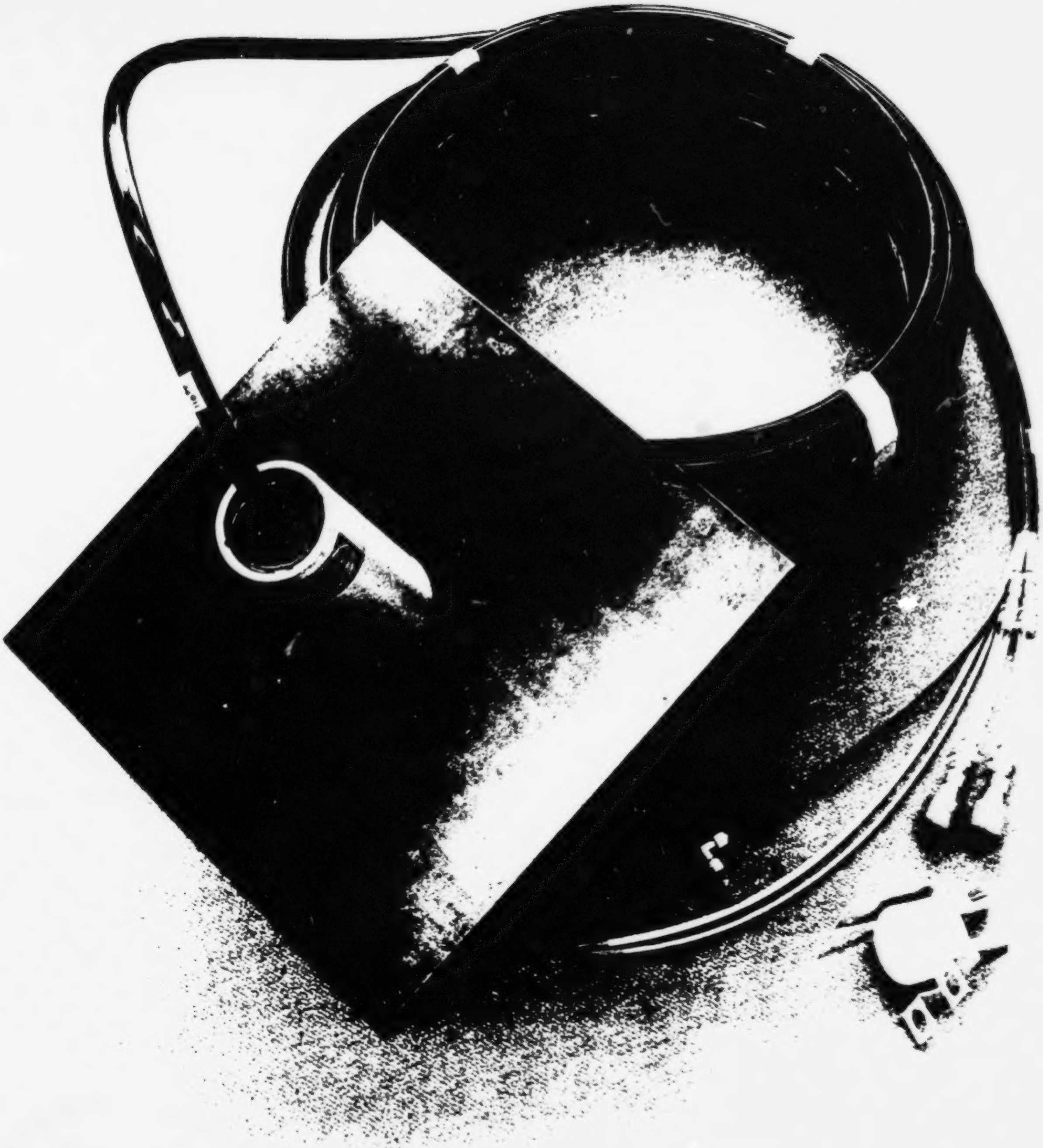
- ADJUST the supply regulator on the indicator, not to exceed the range of the output pressure gauge, and slowly open the direct input valve. Let the purging gas flow until all expected contamination is forced from the transducer and instrument tubes.

5.2 DE-AIRING LIQUID LEADS

Air pockets trapped in the liquid tubes near the reservoir can be removed by gravity flowing the liquid from one of the disconnected tubes held high above the liquid level of the reservoir. once the air pockets are forced into the reservoir actuator, the process can be reversed by lowering the disconnected liquid tube.

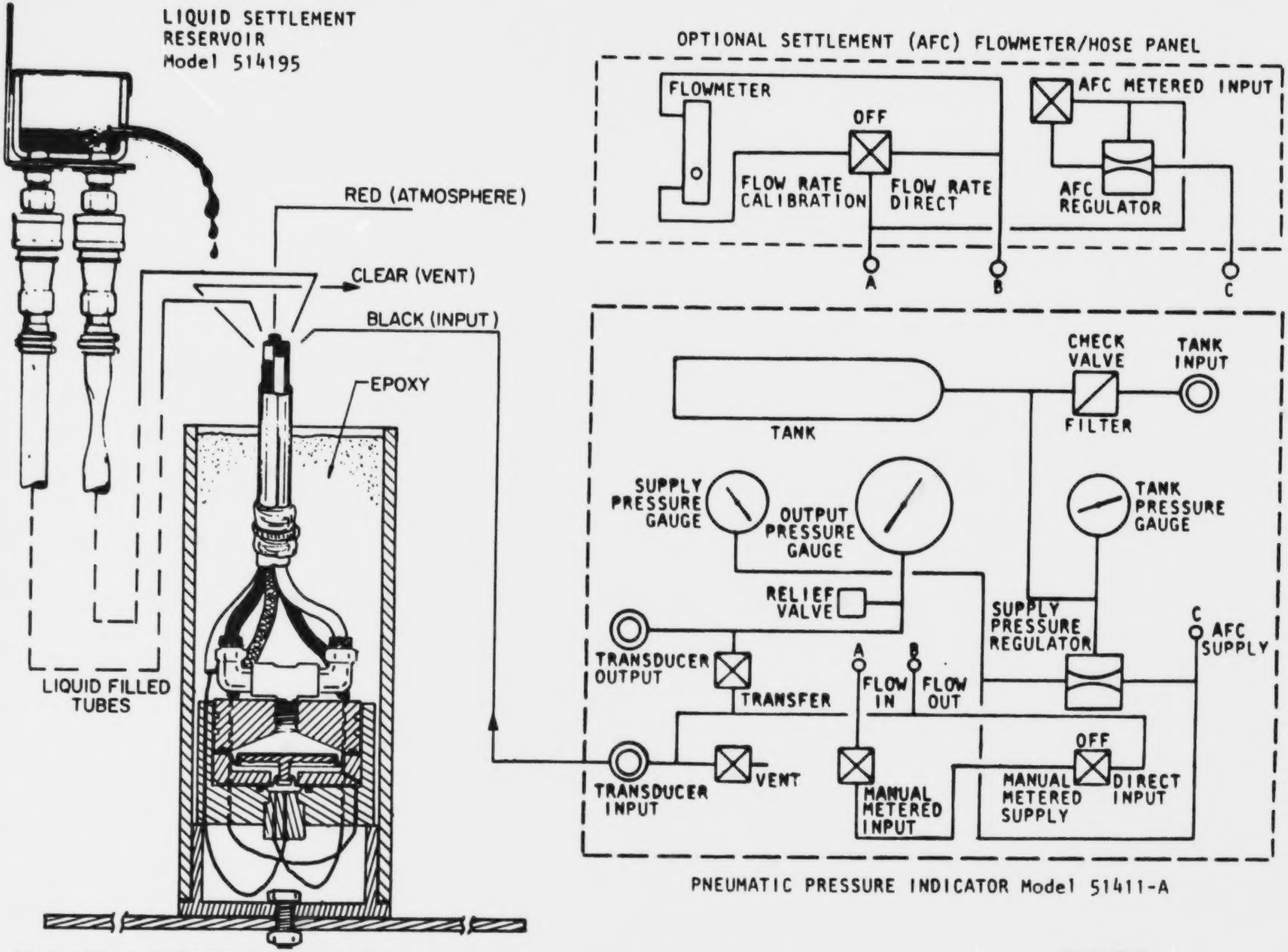
Should the jacketed instrument tubing be damaged to the extent that splicing is necessary, the liquid tubes must then be de-aired by applying liquid under pressure. A special liquid chamber is required for this de-airing procedure.

Field test measurements should be taken prior to filling the splice kit with epoxy.



51408300 Pneumatic Settlement Transducer with
Reservoir and Steel Plate

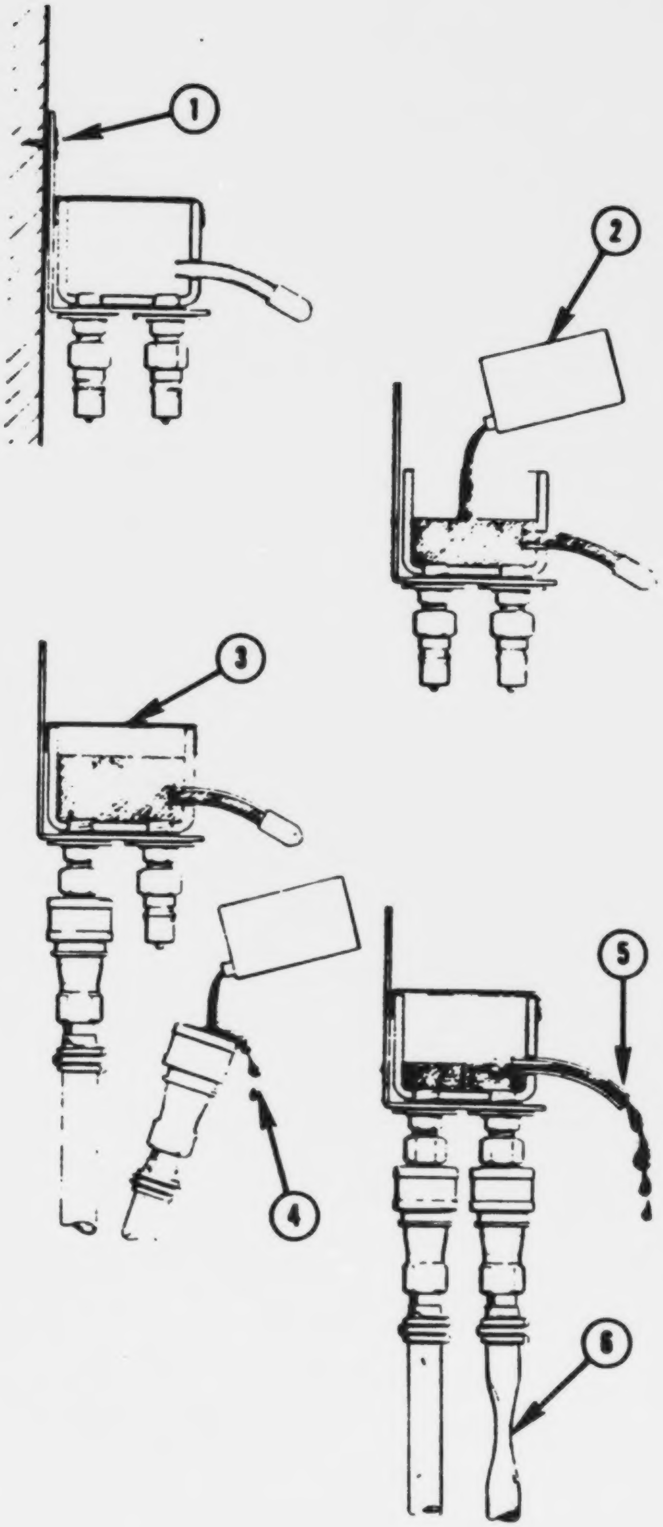
SINCO [illegible] Inc.


LIQUID SETTLEMENT RESERVOIR Model 514195
RED (ATMOSPHERE)
CLEAR (VENT)
BLACK (INPUT)
EPOXY
LIQUID FILLED TUBES
OPTIONAL SETTLEMENT (AFC) FLOWMETER/HOSE PANEL
FLOWMETER
OFF
FLOW RATE CALIBRATION
FLOW RATE DIRECT
AFC METERED INPUT
AFC REGULATOR
A
B
C
CHECK VALVE
TANK INPUT
FILTER
TANK
SUPPLY PRESSURE GAUGE
OUTPUT PRESSURE GAUGE
TANK PRESSURE GAUGE
RELIEF VALVE
SUPPLY PRESSURE REGULATOR
C
AFC SUPPLY
TRANSDUCER OUTPUT
TRANSFER
A
B
FLOW IN
FLOW OUT
OFF
TRANSDUCER INPUT
VENT
MANUAL METERED INPUT
MANUAL METERED SUPPLY
DIRECT INPUT
PNEUMATIC PRESSURE INDICATOR Model 51411-A

23:1 LIQUID SETTLEMENT TRANSDUCER with SETTLEMENT PLATE (Model 51483/23:1)

SETTLEMENT SYSTEM FLOW DIAGRAM

SINCO Slope Indicator Company
Seattle, Washington U.S.A



1 Secure reservoir to stable support and install overflow tube.

2 Remove clear plastic cover and add liquid above overflow tube.

3 Replace cover before making tube connections. (CAUTION: liquid leads are pressurized.)

4 Fill each female socket with liquid prior to connecting them to reservoir.

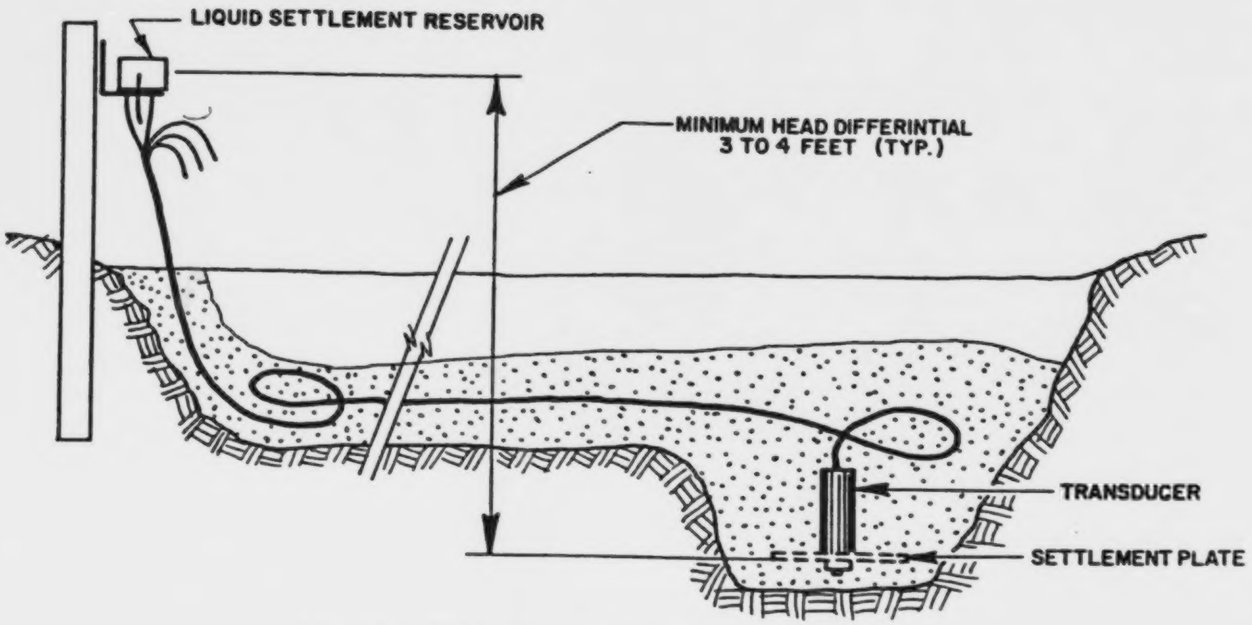
5 Remove the overflow tube cap, allowing any excess liquid to escape.

6 Gently squeeze the clear plastic tube below the coupler to remove any air bubbles that may have been introduced into the system during the connecting of the tubes.

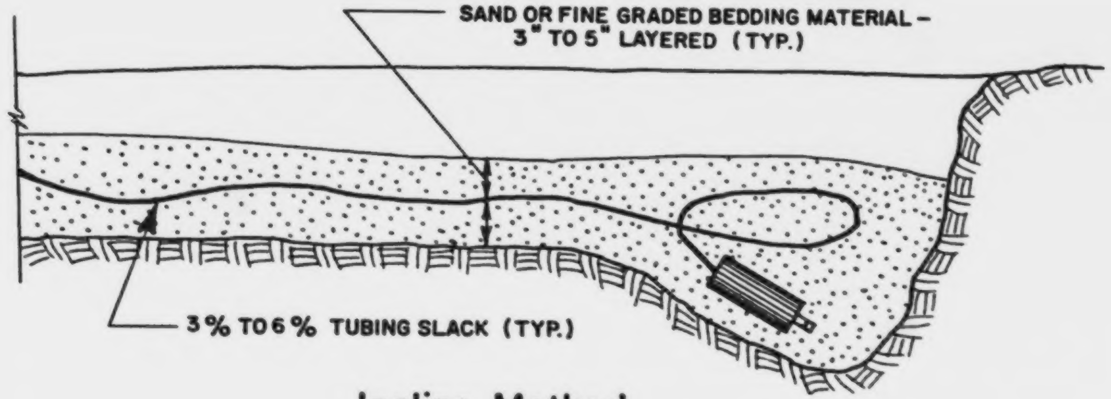
NOTE: To maintain a constant liquid elevation, always add fluid to reservoir and allow the excess to drain off.

INSTALLATION PROCEDURE FOR LIQUID SETTLEMENT RESERVOIR MODEL 514195

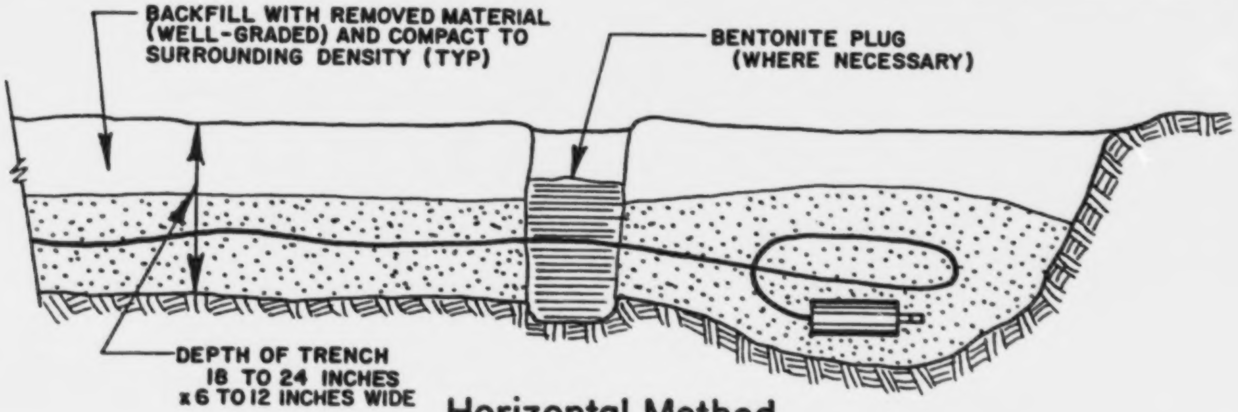
Sinco Slope Indicator Company
Seattle, Washington U.S.A.


LIQUID SETTLEMENT RESERVOIR
MINIMUM HEAD DIFFERINTIAL 3 TO 4 FEET (TYP.)
TRANSDUCER
SETTLEMENT PLATE

Vertical Method (recommended)

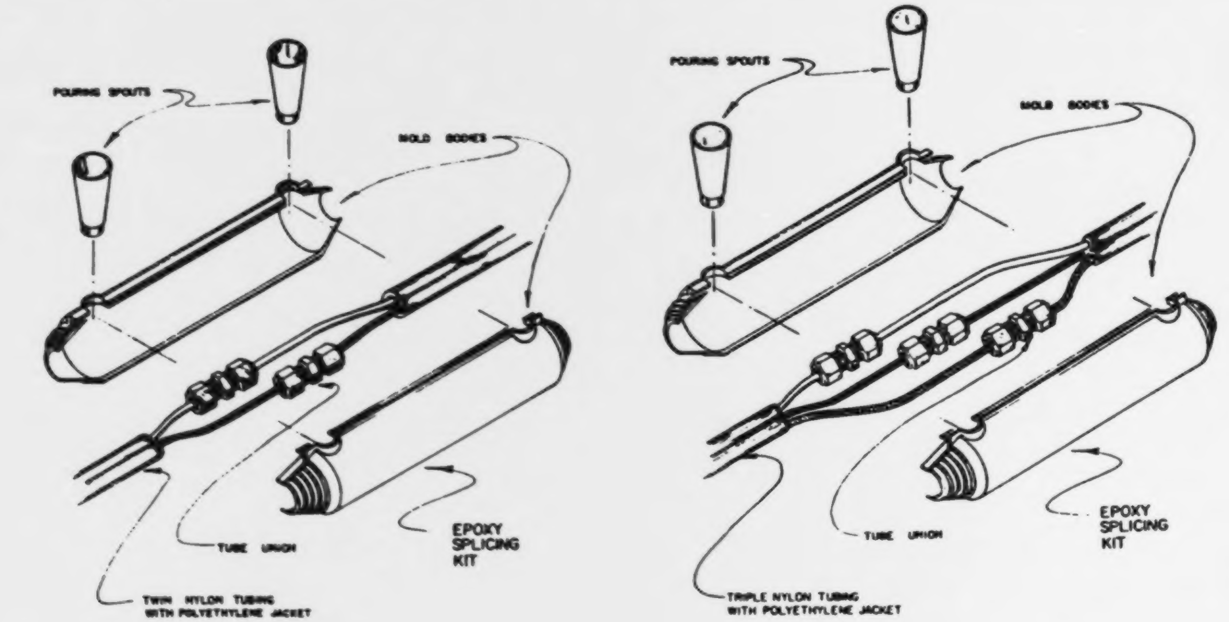

SAND OR FINE GRADED BEDDING MATERIAL - 3" TO 5" LAYERED (TYP.)
3% TO 6% TUBING SLACK (TYP.)

Incline Method

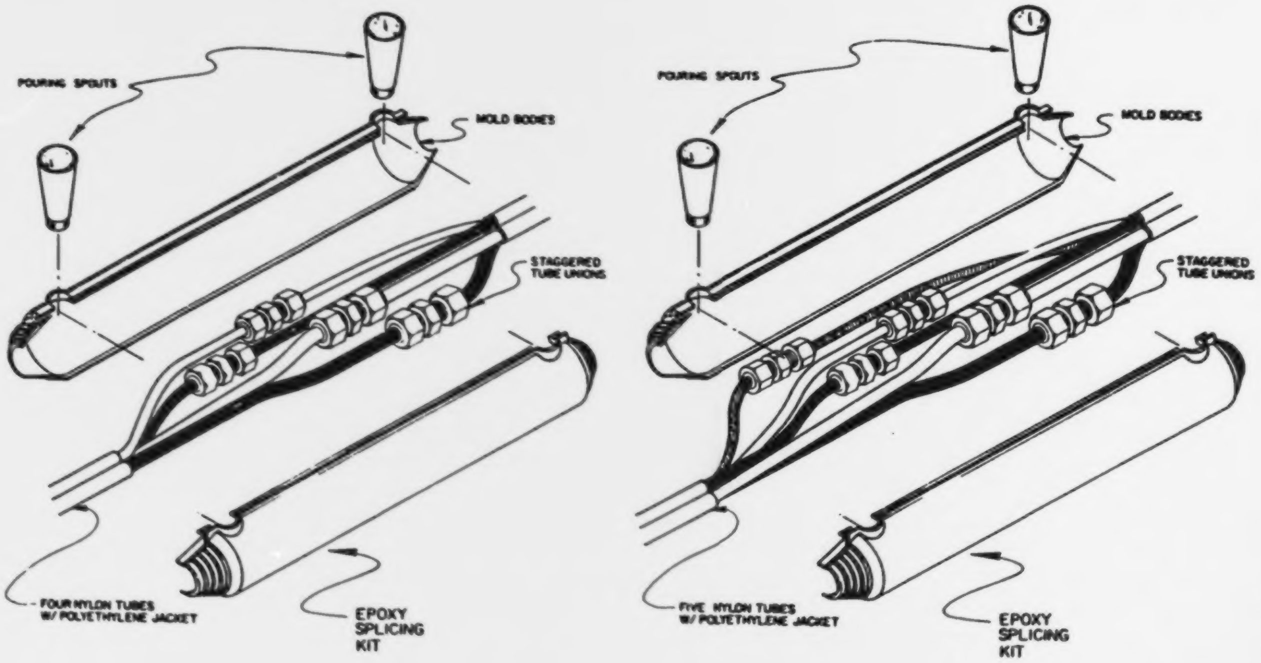

BACKFILL WITH REMOVED MATERIAL (WELL-GRADED) AND COMPACT TO SURROUNDING DENSITY (TYP)
BENTONITE PLUG (WHERE NECESSARY)
DEPTH OF TRENCH 18 TO 24 INCHES x 6 TO 12 INCHES WIDE

Horizontal Method

Fig. 3 INSTALLATION METHODS


POURING SPOUTS
MOLD BODIES
TUBE UNION
EPOXY SPLICING KIT
TWIN NYLON TUBING WITH POLYETHYLENE JACKET
POURING SPOUTS
MOLD BODIES
TUBE UNION
EPOXY SPLICING KIT
TRIPLE NYLON TUBING WITH POLYETHYLENE JACKET

Note: Stagger couplings as needed to fit splicing kit which will vary with the number of tubes used.


POURING SPOUTS
MOLD BODIES
STAGGERED TUBE UNIONS
FOUR NYLON TUBES W/ POLYETHYLENE JACKET
EPOXY SPLICING KIT
POURING SPOUTS
MOLD BODIES
STAGGERED TUBE UNIONS
FIVE NYLON TUBES W/ POLYETHYLENE JACKET
EPOXY SPLICING KIT

SINCO 1154

Pneumatic Tubing Splicing Detail

Printed in USA (1-80)

FIG. 5

SUMMARY OF SETTLEMENT DATA

PROJECT ____________________

Slope
Indicator
Company

DATE	ELEVATION OF PIEZOMETRIC LEVEL (FT./M)							
	WELL #	WELL #	WELL #	WELL #	WELL #	WELL #	WELL #	WELL #

SLOPE INDICATOR COMPANY—3668 ALBION PL. NO. SEATTLE WA. 98103 U.S.A.— PHONE (206) 633-3073

SINCO 1205

PRESSURE EQUIVALENTS

PSI	IN. HG.	MM HG.	KG/CM^2	FT. WATER	IN. WATER	ATM.	KPA	BARS
1	2.0360	51.715	.07031	2.3067	27.680	.06805	6.8948	.06894
5	10.180	258.58	.35155	11.533	138.40	.34025	34.474	.34474
10	20.360	517.15	.70306	23.067	276.80	.68050	68.948	.68948
15	30.540	775.73	1.0547	34.601	415.20	1.0207	103.42	1.0342
30	61.080	1551.5	2.1092	69.201	830.40	2.0415	206.84	2.0684
60	122.16	3102.9	4.2184	138.40	1660.8	4.0830	413.68	4.1368
100	203.60	5171.5	7.0306	230.67	2768.0	6.8050	689.48	6.8948
160	325.76	8274.4	11.249	396.07	4428.8	10.887	1103.2	11.032
200	407.20	10343.	14.061	461.34	5536.0	13.609	1378.9	13.789
250	509.00	12928.	17.576	576.67	6920.0	17.011	1723.7	17.237
300	610.80	15515.	21.092	692.01	8304.0	20.415	2068.4	20.684
400	814.40	20686.	28.122	922.68	11072.	27.218	2757.9	27.579
500	1018.0	25858.	35.155	1153.3	13840.	34.025	3447.4	34.474
600	1221.6	31029.	42.184	1384.0	16608.	40.830	4136.8	41.368
700	1425.2	36201.	49.214	1614.7	19376.	47.632	4826.4	48.264
800	1628.8	41372.	56.245	1845.4	22144.	54.436	5515.8	55.158
1000	2036.0	51715.	70.306	2306.7	27680.	68.050	6894.8	68.948
1500	3054.0	77573.	105.47	3460.1	41520.	102.07	10342.	103.42
2000	4072.0	-----	140.61	4613.4	-----	136.09	13789.	137.89
3000	6108.0	-----	210.92	6920.1	-----	204.15	20684.	206.84
5000	10180.	-----	351.55	11533.	-----	340.25	34474.	344.74
10000	20360.	-----	703.06	23067.	-----	680.50	68948.	689.48
20000	40720.	-----	1406.1	46134.	-----	1360.9	137896.	1378.96

METRIC CONVERSION FACTORS

To Convert	Into	Multiply by
Centimeters	Feet	3.281×10^{-2}
Centimeters	Inches	0.3937
Centimeters	Kilometers	10^{-5}
Centimeters	Meters	0.01
Centimeters	Miles	6.214×10^{-6}
Centimeters	Millimeters	10.0
Centimeters	Mils	393.7
Centimeters	Yards	1.094×10^{-2}
Feet	Centimeters	30.48
Feet	Kilometers	3.048×10^{-4}
Feet	Meters	0.3048
Feet	Miles (Nautical)	1.645×10^{-4}
Feet	Miles (Statute)	1.894×10^{-4}
Feet	Millimeters	304.8
Feet	Mils	1.2×10^{4}
Inches	Centimeters	2.540
Inches	Meters	2.540×10^{-2}
Inches	Miles	1.578×10^{-5}
Inches	Millimeters	25.40
Inches	Mils	1,000.0
Inches	Yards	2.778×10^{-2}
Kilometers	Centimeters	10^{5}
Kilometers	Feet	3,281
Kilometers	Inches	3.937×10^{4}
Kilometers	Meters	1,000.00
Kilometers	Miles	0.6214
Kilometers	Millimeters	10^{6}
Kilometers	Yards	1,094.
Meters	Centimeters	100.0
Meters	Feet	3.281
Meters	Inches	39.37
Meters	Kilometers	0.001
Meters	Miles (Nautical)	5.396×10^{-4}
Meters	Miles (Statute)	6.214×10^{-4}
Meters	Millimeters	1,000.0
Meters	Yards	1.094
Meters	Varas	1.179
Millimeters	Centimeters	0.1
Millimeters	Feet	3.281×10^{-3}
Millimeters	Inches	0.03937
Millimeters	Kilometers	10^{-6}
Millimeters	Meters	0.001
Millimeters	Miles	6.214×10^{-7}
Millimeters	Mils	39.37
Millimeters	Yards	1.094×10^{-3}
Mils	Centimeters	2.540×10^{-3}
Mils	Feet	8.333×10^{-5}
Mils	Inches	0.001
Mils	Kilometers	2.540×10^{-8}
Mils	Yards	2.778×10^{-5}

CALIBRATION RECORD

S-1

SETTLEMENT TRANSDUCER CALIBRATION

3-29-85

Transducer Ser.#	23944
Transducer Model	51408300
Customer name	SINCA LTD.
Customer number	10960
Order number	20350-00
Tubing type	5-TUBE-POLY
Lead length	1000'
Liquid type	50:50, GLY:H20 MIX.
Temperature (deg. F)	68
Readout Guage	HEISE 710-A
SN	S7-816

LIQUID HEAD FEET	TRANSDUCER READING PSI	LINEARITY ERROR FEET
3.000	28.900	.043
4.000	38.100	.012
5.000	47.200	.008-
6.000	56.300	.028-
7.000	65.200	.026-
8.000	74.100	.023-
9.000	83.000	.021-
10.000	91.700	.004
11.000	100.500	.017
12.000	109.300	.031

Sensitivity = 8.921 PSI /FEET
Zero Offset = 2.523 PSI
Calculated Head =(Reading - Offset)/Sensitivity
Calc. Error = Actual Head - Calc. Head

Remarks: FLOWRATE =.1 SCFH @ READING.

Mike Salic

Calibration By MIKE SALIC

SLOPE INDICATOR COMPANY • P.O. BOX C-30316 • SEATTLE, WA. (206) 633-3073

CALIBRATION RECORD

S-2

SETTLEMENT TRANSDUCER CALIBRATION

3-29-85

Transducer Ser.#	23945
Transducer Model	51408300
Customer name	SINCA LTD.
Customer number	20350
Order number	10960-00
Tubing type	5-TUBE-POLY.
Lead length	985FT
Liquid type	50:50, GLY:H2O MIX.
Temperature (deg. F)	68
Readout Guage	HEISE 710-A
SN	S7-816

LIQUID HEAD FEET	TRANSDUCER READING PSI	LINEARITY ERROR FEET
3.000	30.700	.041
4.000	40.000	.002-
5.000	49.000	.010-
6.000	58.000	.019-
7.000	67.000	.027-
8.000	75.800	.013-
9.000	84.600	.001
10.000	93.500	.003
11.000	102.400	.006
12.000	111.200	.020

Sensitivity = 8.924 PSI /FEET
Zero Offset = 4.290 PSI
Calculated Head =(Reading - Offset)/Sensitivity
Calc. Error = Actual Head - Calc. Head

Remarks: FLOWRATE =.1 SCFH @ READING.

Calibration By MIKE SALIC

S-3

SETTLEMENT TRANSDUCER CALIBRATION

3-29-85

Transducer Ser.#	23946
Transducer Model	51408300
Customer name	SINCA LTD.
Customer number	20350
Order number	10960-00
Tubing type	5-TUBE-POLY.
Lead length	645FT
Liquid type	50:50, GLY:H2O MIX.
Temperature (deg. F)	68
Readout Guage	HEISE 710-A
SN	S7-816

LIQUID HEAD FEET	TRANSDUCER READING PSI	LINEARITY ERROR FEET
3.000	29.800	.037
4.000	38.900	.008
5.000	47.900	.009-
6.000	56.800	.015-
7.000	65.800	.032-
8.000	74.500	.015-
9.000	83.300	.010-
10.000	92.000	.007
11.000	100.900	.001
12.000	109.500	.029

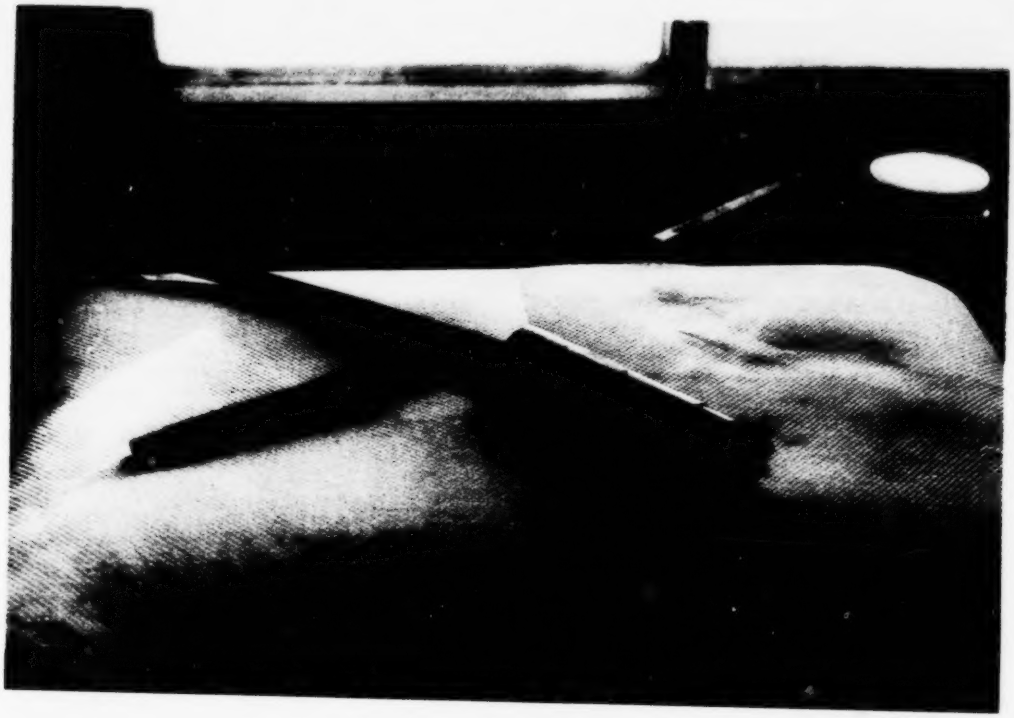
Sensitivity = 8.848 PSI /FEET
Zero Offset = 3.580 PSI
Calculated Head =(Reading - Offset)/Sensitivity
Calc. Error = Actual Head - Calc. Head

Remarks: FLOWRATE =.1 SCFH @ READING.

Calibration By MIKE SALIC

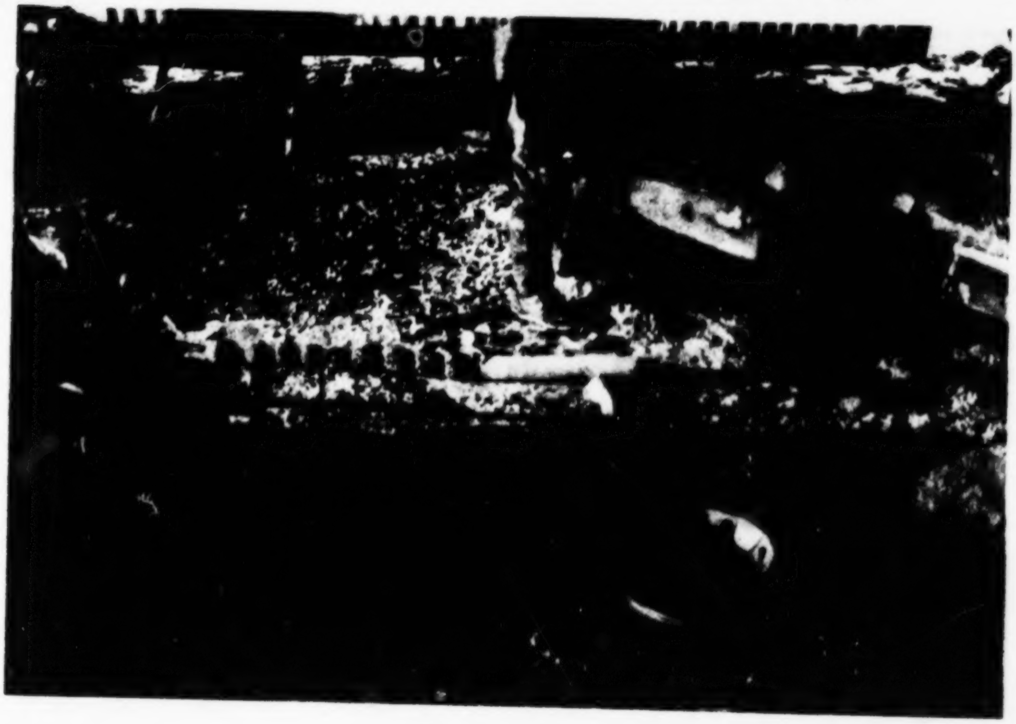
APPENDIX 7

Photographs



PHOTOGRAPH NO. 1

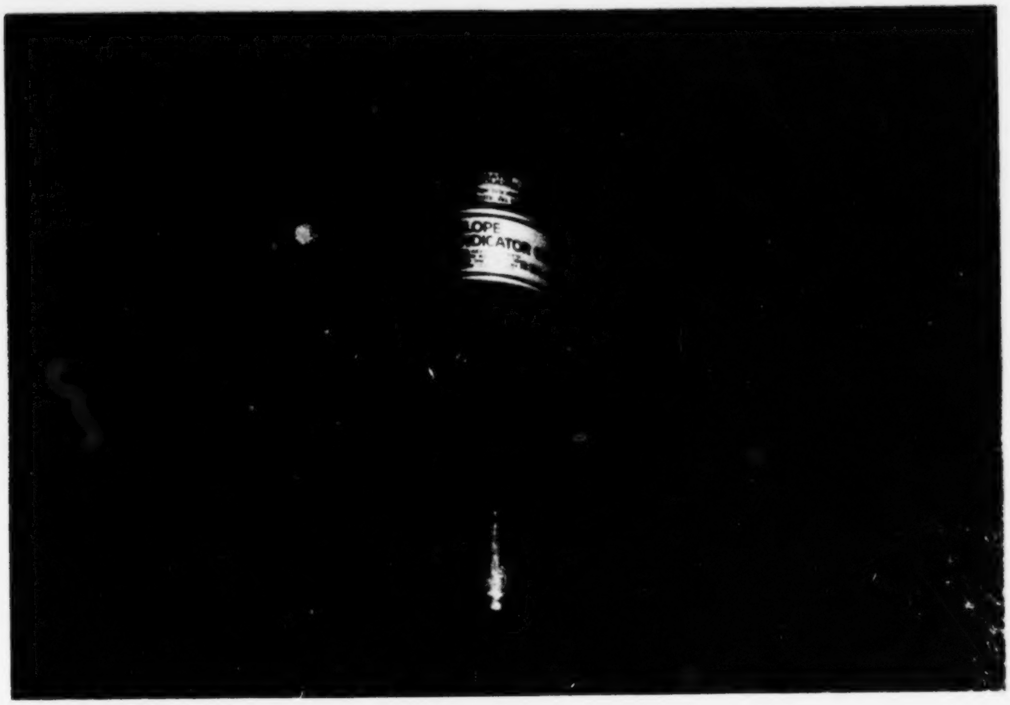
Pneumatic pore pressure transducer (piezometer tip).



PHOTOGRAPH NO. 2

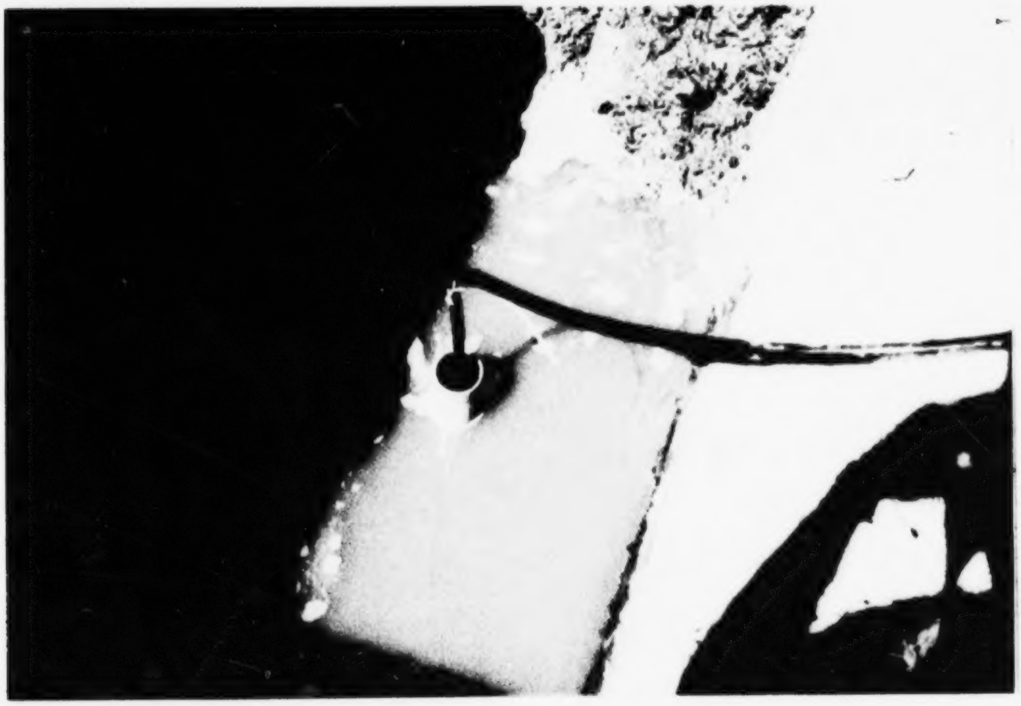
Piezometer pre-assembly, canvas encasement containing graded sand and piezometer tip, bentonite pellet filled mesh bags and ballast weight.

Geotechnical Consultants Ltd.



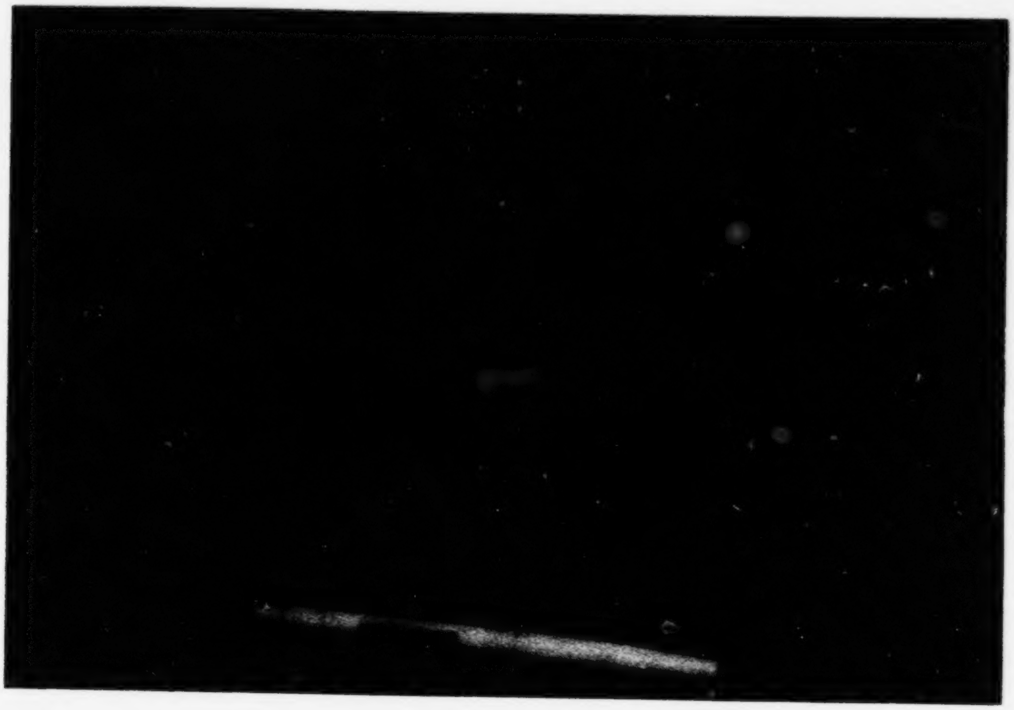
PHOTOGRAPH NO. 3

Settlement sensor transducer.



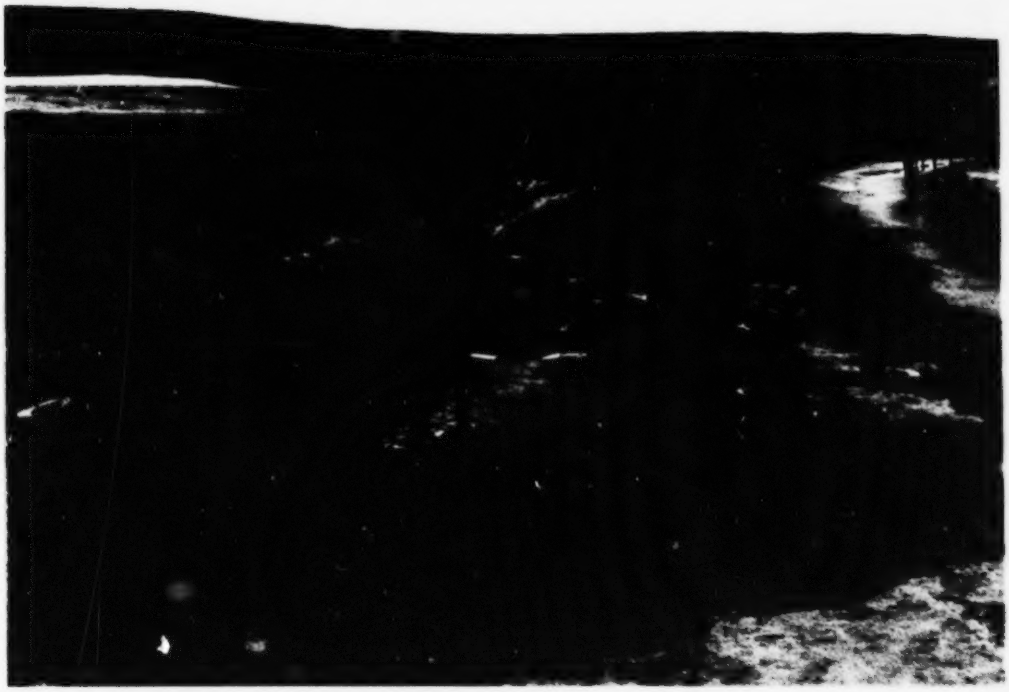
PHOTOGRAPH NO. 4

Settlement transducer placed in backhoe excavated pit.



PHOTOGRAPH NO. 5

Piezometer line splice with epoxy mold in place.

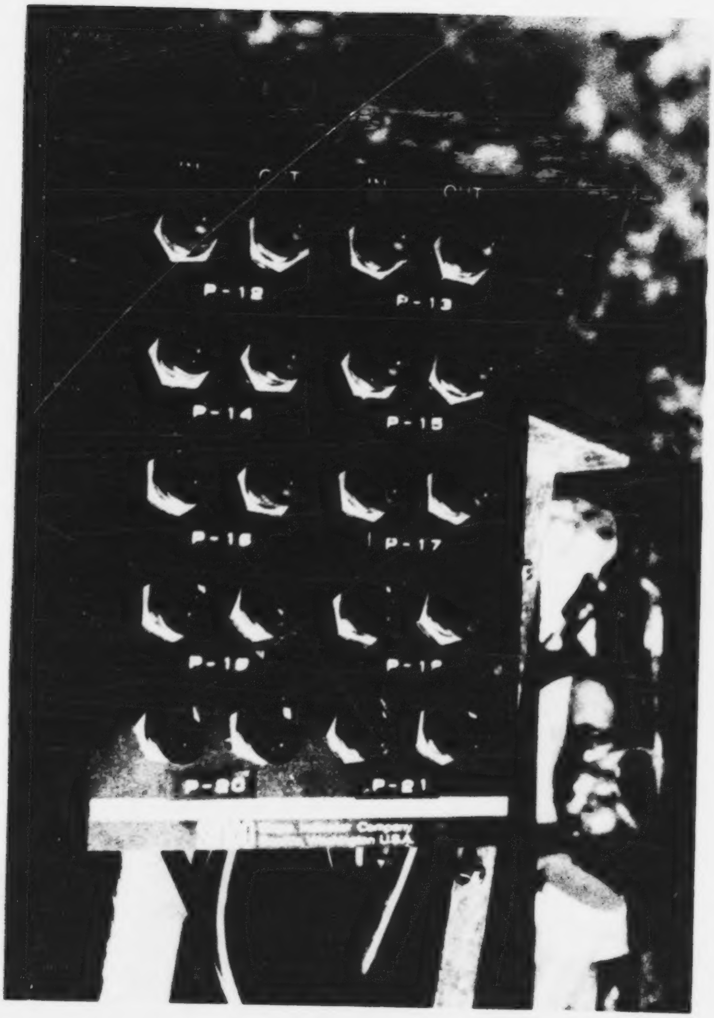


PHOTOGRAPH NO. 6

Individual trenches to well head locations, Nest No. 2.

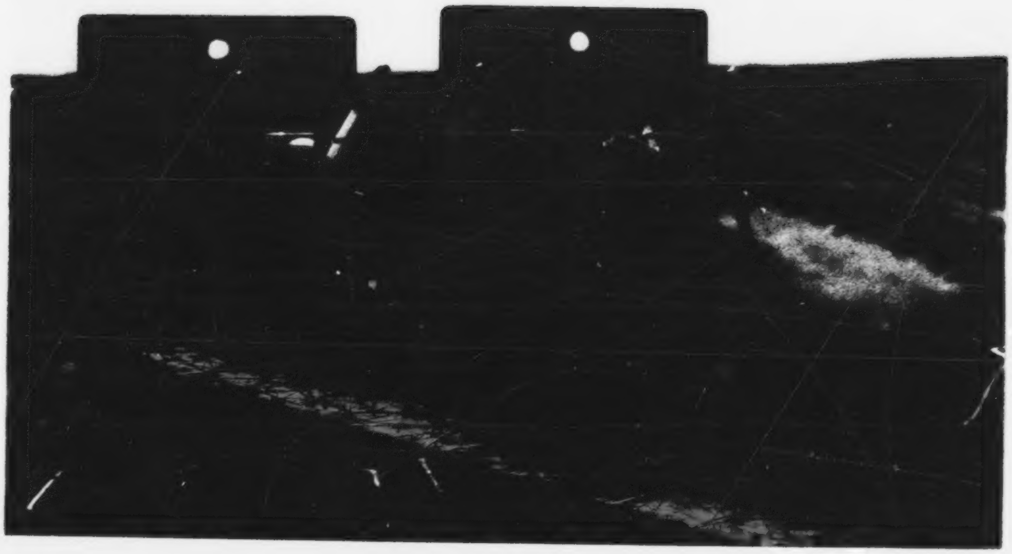
PHOTOGRAPH NO. 7

Main trench and leads. Backfill/bedding sand being hand placed.


IN
OUT
IN
OUT
P-12
P-13
P-14
P-15
P-16
P-17
P-18
P-19
P-20
P-21

PHOTOGRAPH NO. 8

Terminal connections Piezometers P12 to P21 inc.



PHOTOGRAPH NO. 9

Settlement sensor terminations and reservoirs.

PHOTOGRAPH NO. 10

General Arrangement of piezometer and settlement sensor terminal pipes/connections, covers removed.

APPENDIX 8

Field Notes, Miscellaneous Laboratory Notes and Details

APPENDIX 8

Field Notes, Miscellaneous Laboratory Notes and Details

Installation Records

Survey Traverse

Confined Compression Tests

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Page ________ of ________
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN

By DH Date ________

TEST HOLE NO P-1

DRILLING STARTED April 15/85 DRILLING FINISHED April 15/85

Type of DRILLING EQUIPMENT CME OPERATOR C.O.

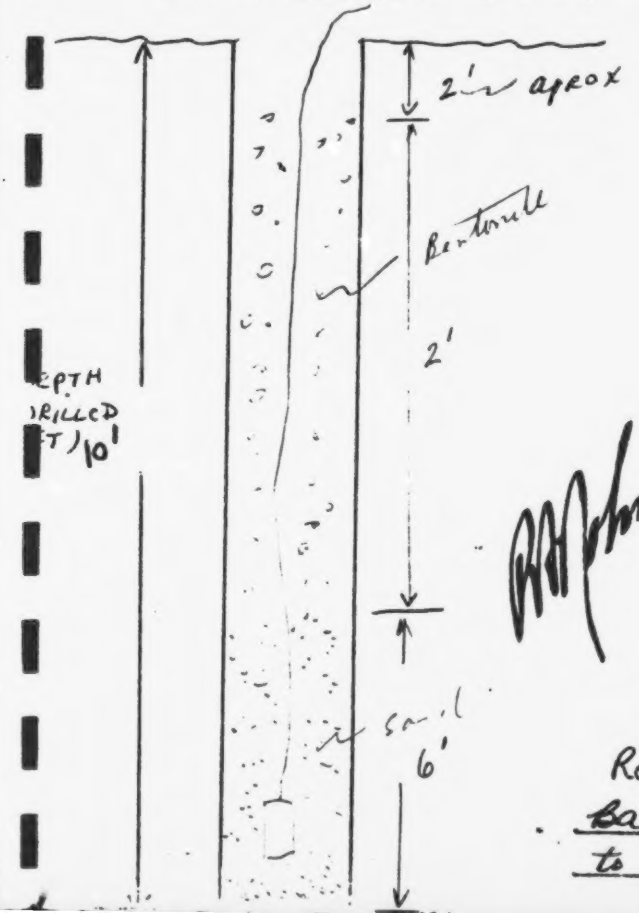
TRANSDUCER SERIAL NO 23058 TOTAL MEASURED LENGTH (ft) 37

LOCATION of TRANSDUCER FROM GROUND SURFACE (FT) 7'

DATE INSTALLED April 15/85 @ 3:50 DATE GROUTED No. Grout

CONSUMABLE QUANITIES ________

INSTALLATION (N.T.S)



RA Johnson

TRANSDUCER PRESSURE READINGS

DATE	TIME	PRESSURE (PS
April 16/.	3:30 P.m	1.4

REMARKS. Transducer installed without Bag. Frac sand to 4'. Bentonite Pellets to 2' Below Ground surface.

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Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date

TEST HOLE NO P-2

DRILLING STARTED April 15/85 DRILLING FINISHED April 15/85

TYPE OF DRILLING EQUIPMENT CME OPERATOR C.O.

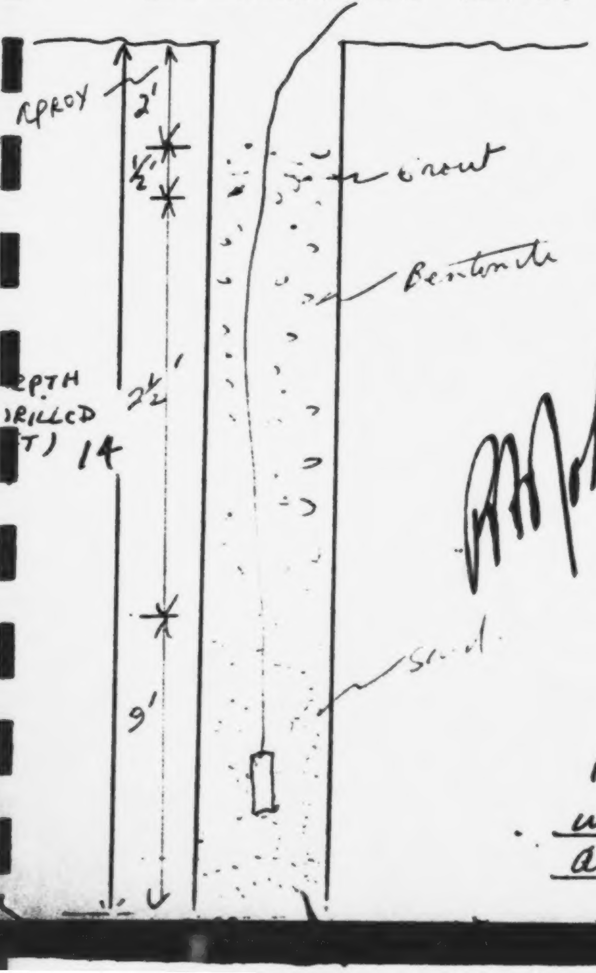
TRANSDUCER SERIAL NO 23056 TOTAL MEASURED LENGTH (FT) 45'

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 9½'

DATE INSTALLED April 15/85 DATE GROUTED April 17/85

CONSUMABLE QUANITIES Grout from P-7 Batch

INSTALLATION (N.T.S)



RH Johnson

TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PS
April 16/85	2:30 P.M	2 Before Grout
✓ 17/85	10:05 AM	2.41 After Grout

REMARKS. Transducer installed in Bag with 26" of Frac sand. Bentonite Pellets above sand 40"

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Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN

By DA Date ______

TEST HOLE NO P-3

DRILLING STARTED April 16/85 DRILLING FINISHED April 16/85

TYPE OF DRILLING EQUIPMENT CME OPERATOR C.O.

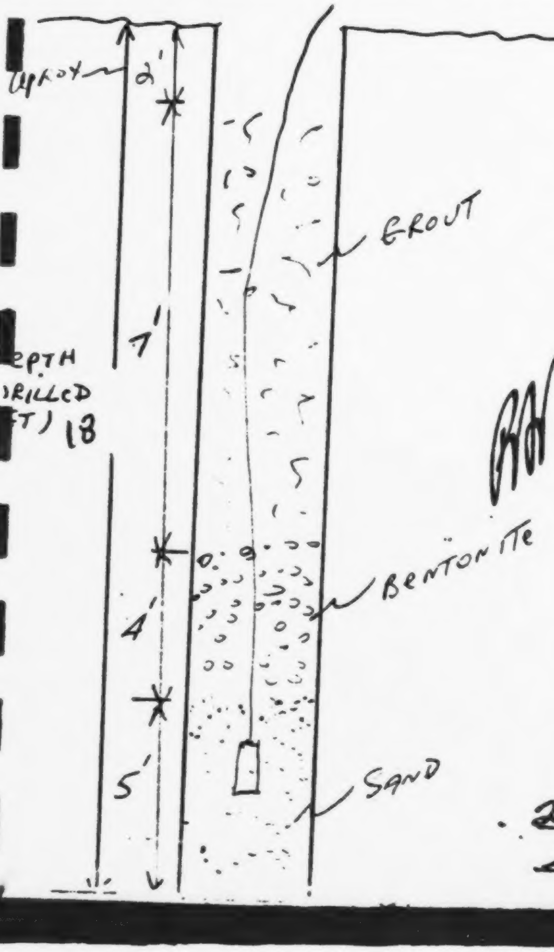
TRANSDUCER SERIAL NO 23062 TOTAL MEASURED LENGTH (FT) 49:

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 15

DATE INSTALLED April 16/85 @ 9:15 DATE GROUTED April 17/85

CONSUMABLE QUANITIES Grout from P-7 Batch

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PS
April 16/85	2:55 P.M	5.5 B. Grout
April 17/85	9:45 Am	7.0' After Grout

RH Johnson

REMARKS. Transducer installed in Bag with 24" of sand & Bentonite Pellets 10" above sand.

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Page ______ of ______
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-4

DRILLING STARTED April 15/85 DRILLING FINISHED April 15/85

TYPE OF DRILLING EQUIPMENT CME OPERATOR C.O.

TRANSDUCER SERIAL NO 23061 TOTAL MEASURED LENGTH (FT) 60

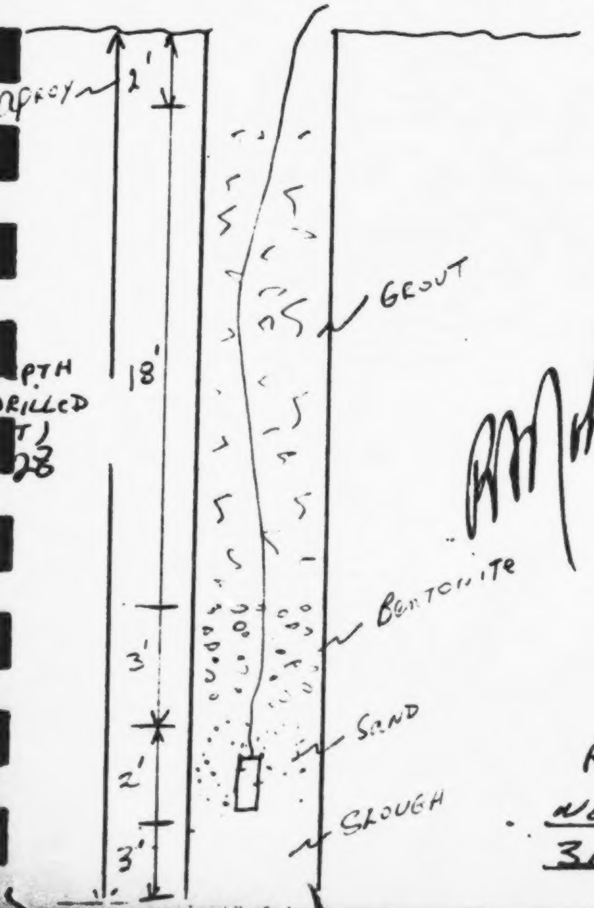
LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 25'

DATE INSTALLED April 15/85 DATE GROUTED April 17/85

CONSUMABLE QUANITIES Grout from P-7 Batch

The transducer became lodged @ 15½' on april 15/85. On april 16/85 it was pushed down to 25' with the solid stem auger. Sand & Bentonite were again installed B. Grout.

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READINGS

DATE	TIME	PRESSURE (PSI
April 16/85	2:40 P.M	14.8 B. Grout
April 17/85	10:00 A.M	11.1' After Grout

REMARKS. Transducer installed in Bag with 24" of frac sand. Bentonite Pellets 36" above sand

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Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-5

DRILLING STARTED April 12/35 DRILLING FINISHED April 12/35

TYPE OF DRILLING EQUIPMENT CME OPERATOR C.O

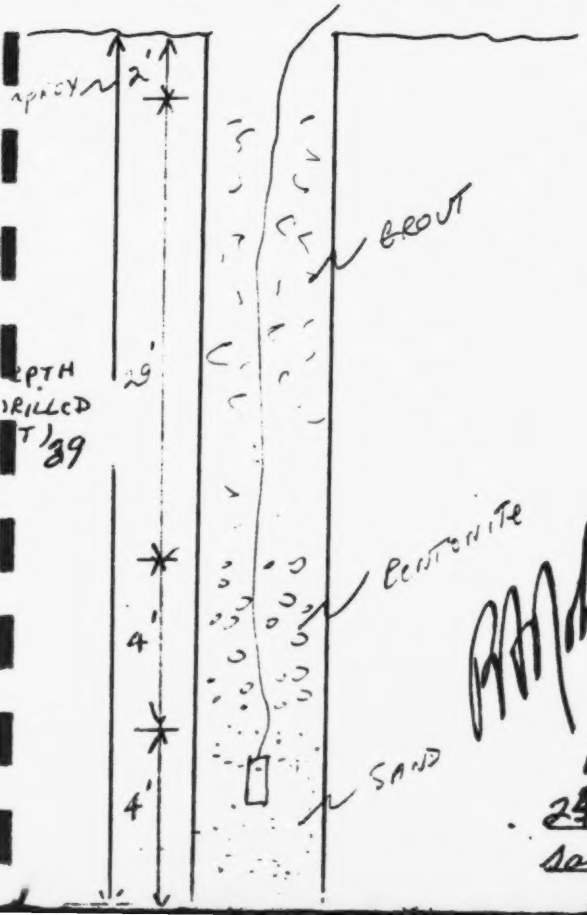
TRANSDUCER SERIAL NO 23063 TOTAL MEASURED LENGTH (FT) 69½

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 37'

DATE INSTALLED April 12/35 DATE GROUTED April 12/85

CONSUMABLE QUANITIES Grout fun P-6

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READINGS

DATE	TIME	PRESSURE (PSI	
April 12/35	3:15 P.M	15.5	B. Grout
April 17/35	9:20AM	15.4	After Grout

REMARKS. Transducer installed in Bag with 24" of sand. Bentonite Pellets to 51" above sand.
15" long weight used @ Bottom of Bag,

Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DA Date ______

TEST HOLE NO P-6

DRILLING STARTED april 12/85 DRILLING FINISHED april 12/85

TYPE OF DRILLING EQUIPMENT CME OPERATOR C.O

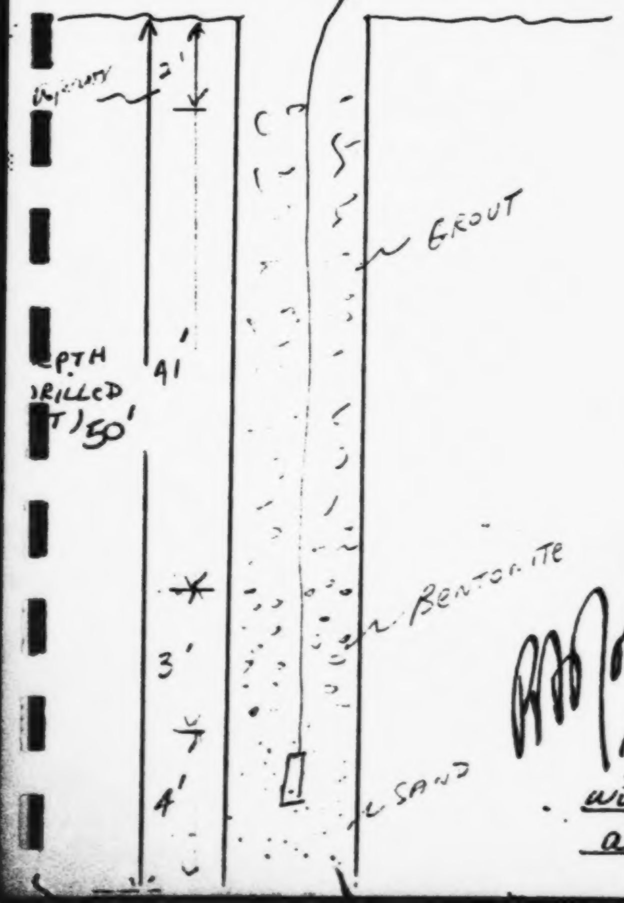
TRANSDUCER SERIAL NO 23054 TOTAL MEASURED LENGTH (FT) 80'

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 48'

DATE INSTALLED april 12/85 DATE GROUTED april 12/85

CONSUMABLE QUANITIES Grout - 10 Bags of Cement (50)
1 Bag of Gel.

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READINGS

DATE	TIME	PRESSURE (PSI
april 12/85	1:45 P.m	29 B. Grout
april 16/85	3:10 P.m	23.4 After Grout

R B Johnson

REMARKS. Transducer installed in Bag with 24" of Sand. Bentonite Pellets ~~±~~ 32" above sand.
Weight 15" long on bottom of Bag;

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Page ______ of ______
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN By DH Date ______

TEST HOLE NO P-7

DRILLING STARTED April 16/85 DRILLING FINISHED April 16/85

TYPE OF DRILLING EQUIPMENT 1250 Failing OPERATOR D.S.

TRANSDUCER SERIAL NO 23060 TOTAL MEASURED LENGTH (FT) 90'

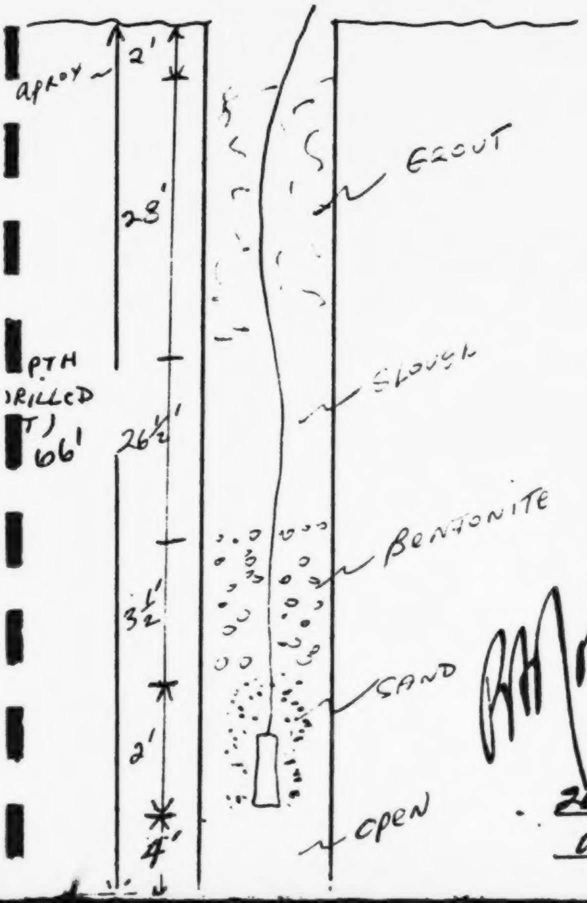
LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 62'

DATE INSTALLED April 16/85 @ 5:30 Pm DATE GROUTED April 17/85

CONSUMABLE QUANITIES Grout: 12 Bags of Cement (50)
1/2 Bag Gel.

Grout hose only to 30' Below Ground surface

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READINGS

DATE	TIME	PRESSURE (PSI)
April 16/85	5:40 P.M.	27.7 B. Grout
April 17/85	7:45 AM	27.7 〃 〃
April 17/85	9:30 AM	34.2 after Grout

RH Johnson

REMARKS. Transducer installed in Bag with 24" sand. Bentonite Pellets 40" above sand Weight 15" long in Bottom of Bag.

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Page ______ of ______
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-8

DRILLING STARTED April 15/85 DRILLING FINISHED April 15/85

TYPE OF DRILLING EQUIPMENT 1250 Failing's OPERATOR D.S.

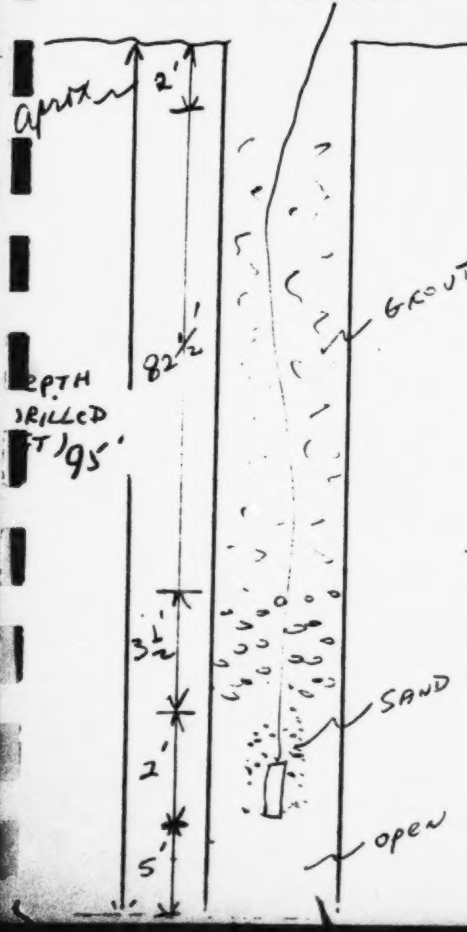
TRANSDUCER SERIAL NO 23050 TOTAL MEASURED LENGTH (FT) 114

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 90'

DATE INSTALLED April 15/85 - 6:00 P.M. DATE GROUTED April 17/85

CONSUMABLE QUANTITIES Grout: 12 Bags Cement (50)
1/2 Bag Gel.

INSTALLATION (N.T.S)



R Johnson

TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PS
Apr. 15/85	6:10 P.M.	41.3 Before Grout
Apr 17/85	9:00 A.M.	52.6 after Grout

REMARKS. Transducer in Bag with 24" Sand
Bentonite Pellets 40" above Sand.
Weight 15" long below bag.

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Page ________ of ________
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ________

TEST HOLE NO P-9

DRILLING STARTED april 10/85 DRILLING FINISHED april 11/85

TYPE OF DRILLING EQUIPMENT 1250 Failing OPERATOR D.S

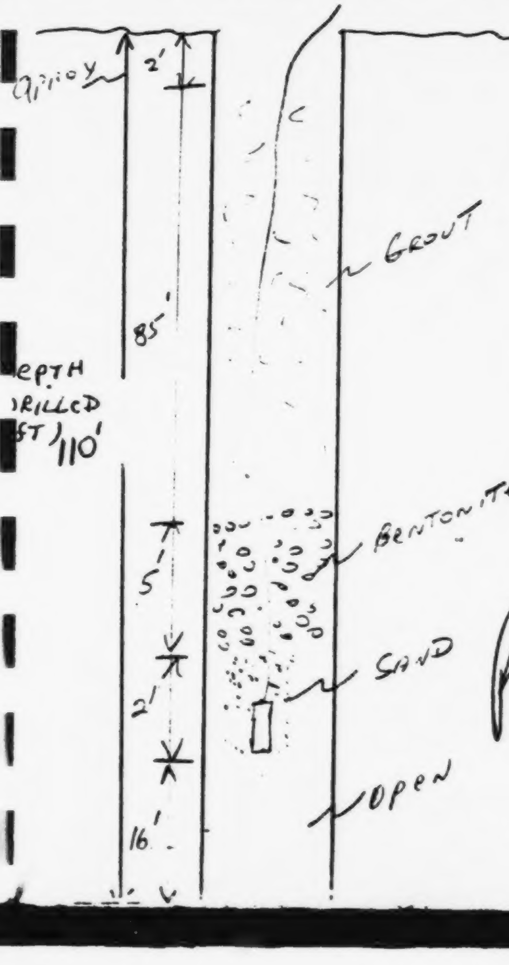
TRANSDUCER SERIAL NO 23052 TOTAL MEASURED LENGTH (FT) 113

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 94

DATE INSTALLED april 11/85 @ 3:30 P.M DATE GROUTED april 12/85

CONSUMABLE QUANITIES Grout 10 Bag Cement (50)
1 " Gel.

INSTALLATION (N.T.S)



RA Johnson

TRANSDUCER PRESSURE READING.

DATE	TIME	PRESSURE (PS
Apr 11/85	4:50 P	42.6 B. Grout
" 12/85	1:30 P.M	42.21 " "
" 17/85	9:05 AM	40.6 After Grout

REMARKS. Transducer in Bag of Sand 24" long. Bentonite pellets to 60" above sand
weight. 15" Arms on Bottom of Bag.

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Page ________ of ________
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date

TEST HOLE NO P-10

DRILLING STARTED April 9/85 DRILLING FINISHED April 9/85

TYPE OF DRILLING EQUIPMENT 1250 Failing OPERATOR D.S.

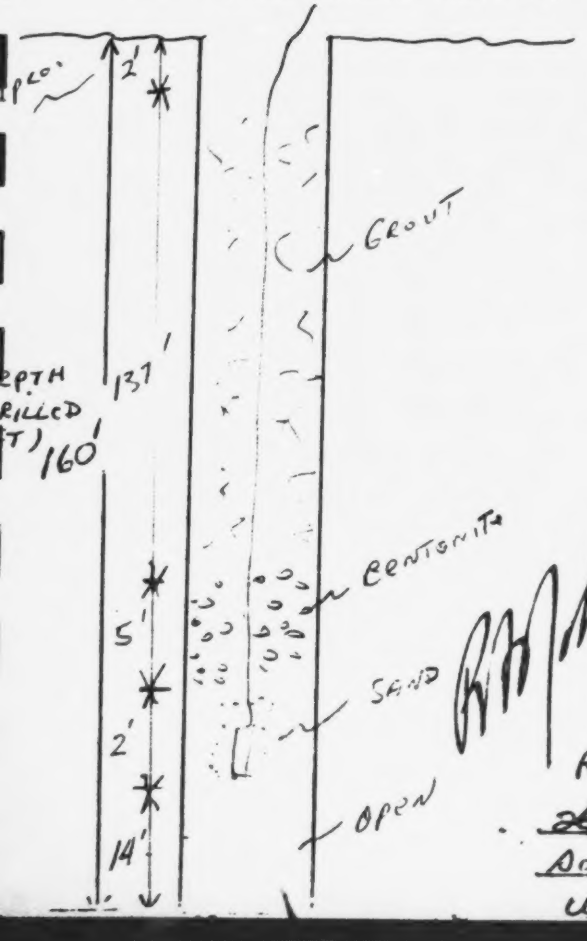
TRANSDUCER SERIAL NO 23064 TOTAL MEASURED LENGTH (FT) 180

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 146.0

DATE INSTALLED April 10/85 @ 12:10 P.m. DATE GROUTED April 10/85

CONSUMABLE QUANITIES Grout - 11 Bags Cement (50)
1 - Gel

INSTALLATION (N.T.S)



R B Johnson

TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PS
April 10/85	2:50 P.m	64.2 B. Grout
" "	3:45 P.m	85 " During Grout
" "	4:10 P.m	83.5 after "
" "	5:30 P.m	82.6 " "
" 11/85	7:30 A.m	73 " "

REMARKS. Transducer in Bag with sand 24" long. Bentonite pellets 60" above Sand.
Weight 36" long on Bottom of the Bag.

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Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DA Date ______

TEST HOLE NO P-11

DRILLING STARTED April 8/85 DRILLING FINISHED April 9/85

Type of DRILLING EQUIPMENT 1250 Faders OPERATOR D.S.

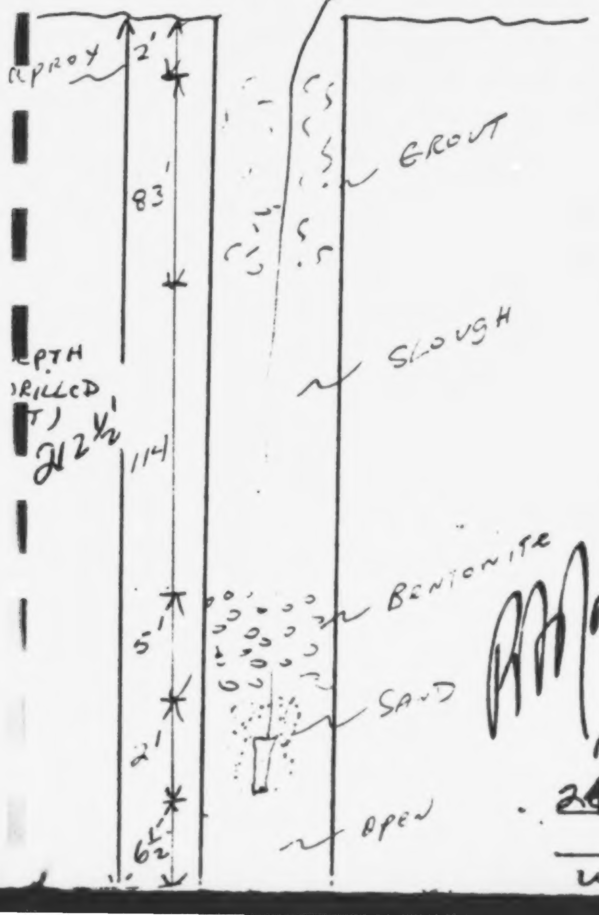
TRANSDUCER SERIAL NO 23046 TOTAL MEASURED LENGTH (FT) 238

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 206

DATE INSTALLED April 9/85 @ 12:00 P.m DATE GROUTED April 10/85

CONSUMABLE QUANITIES Grout - 12 Bags Cement (50)
1/2 Bag Revert - 1 " Gel.

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READING

DATE	Time	PRESSURE (PSI
Apr 9/85	12:20 P.m	90 B. Grout
" 10/85	10:00 Am	90 " "
" 17/85	9:30 a.m	90 after grout

REMARKS. Transducer in Bag of sand 24" long, Bentonite pellets 60" above Sand
Weight: 36" long on Bottom of the Base.

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Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-12

DRILLING STARTED March 11/85 DRILLING FINISHED March 12/85

TYPE OF DRILLING EQUIPMENT 1250 Failing OPERATOR D. SCHMIDT

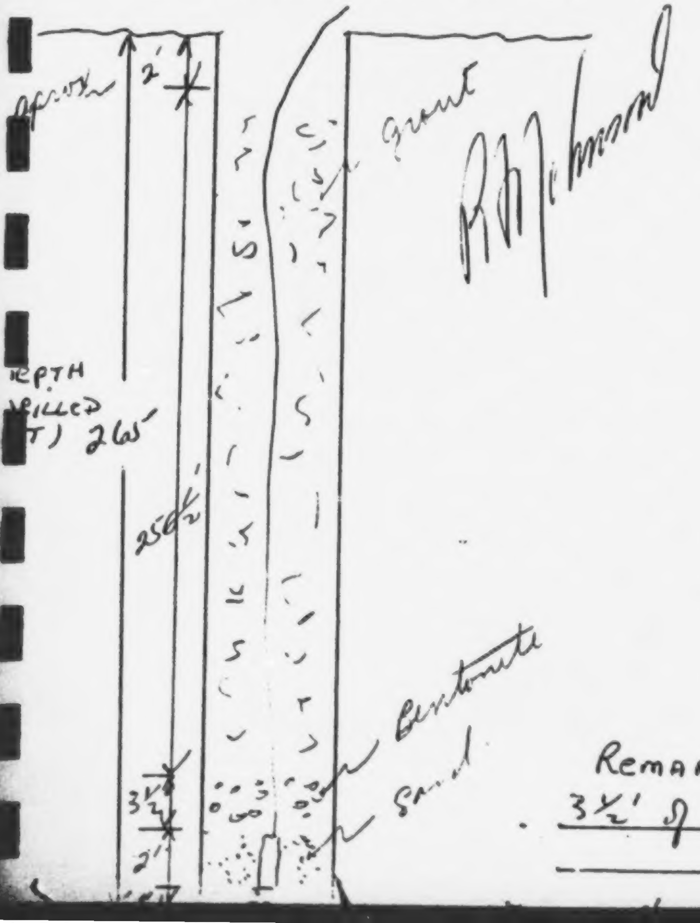
TRANSDUCER SERIAL NO 23048 TOTAL MEASURED LENGTH (FT) 30

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 264'

DATE INSTALLED March 12/85 @ 6:30 Pm DATE GROUTED March 13/85

CONSUMABLE QUANITIES Grout 25 Bags Cement c 2 Gel.

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READINGS

DATE	TIME	PRESSURE (PSI)
March 12/85		134.5 B. Grout
Mar 13/85	8:15 AM	130.7 B. Grout
Apr. 3/85	9:40 AM	117 after grout.

REMARKS. Transducer in Bag of Sand 2' long
3½' of Pellets above sand.

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Page ______ of ______
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-13 (A)

DRILLING STARTED March 6/85 DRILLING FINISHED March 7/85

Type of DRILLING EQUIPMENT 1250 FAILING OPERATOR R. STOLAR

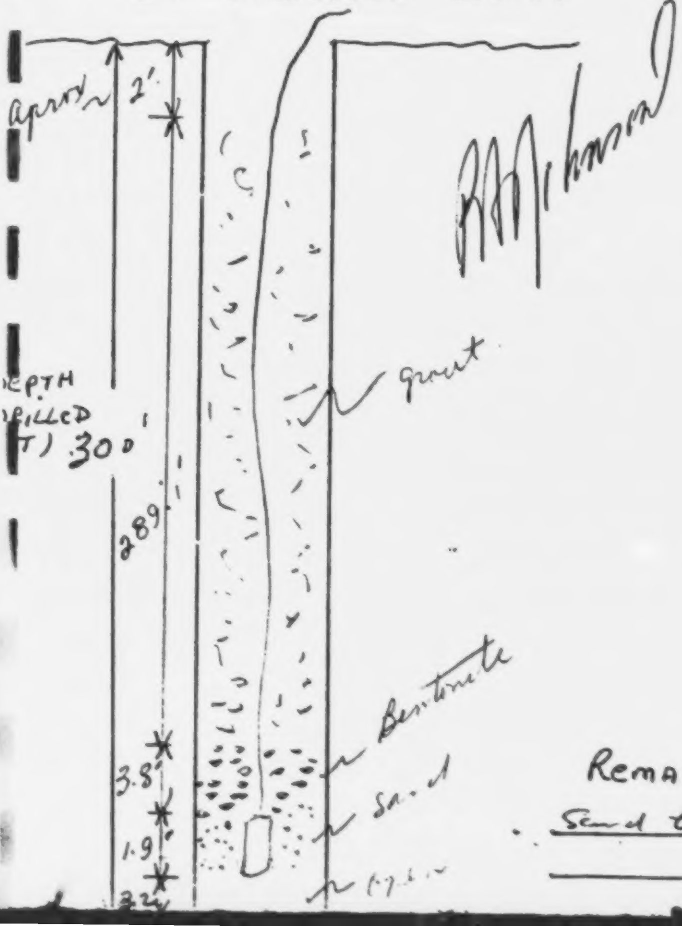
TRANSDUCER SERIAL NO 23066 TOTAL MEASURED LENGTH (FT) 325

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 296.8

DATE INSTALLED March 7/85 DATE GROUTED March 8/85

CONSUMABLE QUANITIES Grout 24 Bags to type 50, 3 Bags Gel.

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READINGS

DATE	Time	PRESSURE (PSI
MARCH 8/85		167.6 BEFORE GROUT.
Mar 11/85		133.1 after grout
Apr 3/85	9:30 AM	131.5

REMARKS. Transducer in Canvas Bag of fine Sand to 1.9', Bentonite 3.8' above Sand.

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Page ______ of ______
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-13

DRILLING STARTED Dec 10/84 DRILLING FINISHED Dec 13/84

Type of DRILLING EQUIPMENT 1250 FAILING OPERATOR D Schmidt.

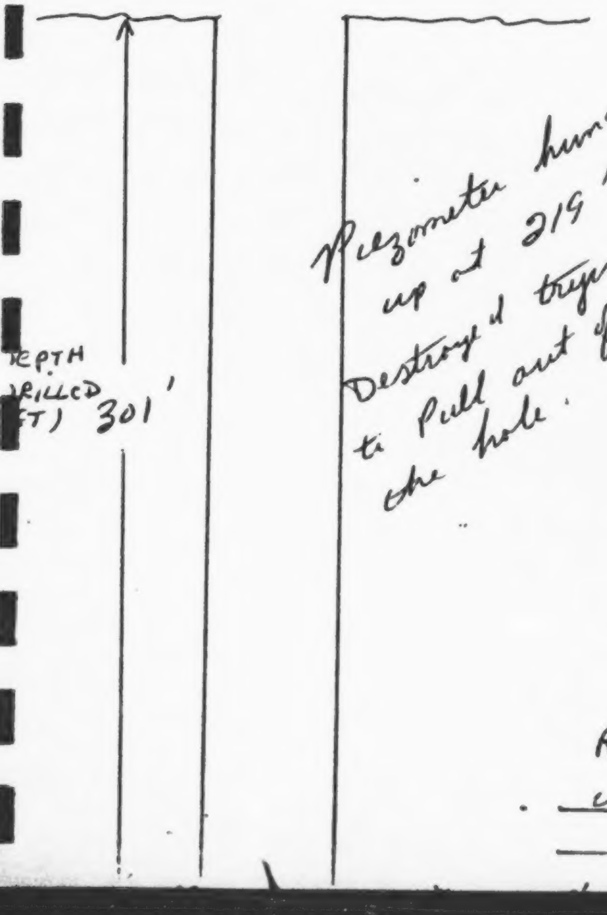
TRANSDUCER SERIAL NO 23047 TOTAL MEASURED LENGTH (FT) 34

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) ______

DATE INSTALLED Dec 13/84 DATE GROUTED March 6/85

CONSUMABLE QUANITIES Grout - 24 Bags Cement & 3 Gel. on March 6/85
Drilling 6 Bags Gel.

INSTALLATION (N.T.S)



Piezometer hung up at 219' Destroyed trying to pull out of the hole.

TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PS

REMARKS. This hole is to be redrilled in 1985 & new Transducer installed

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Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-14

DRILLING STARTED NOV 27/84 DRILLING FINISHED DEC 7/84

TYPE OF DRILLING EQUIPMENT 1250 FAILING OPERATOR D. SCHMIDT

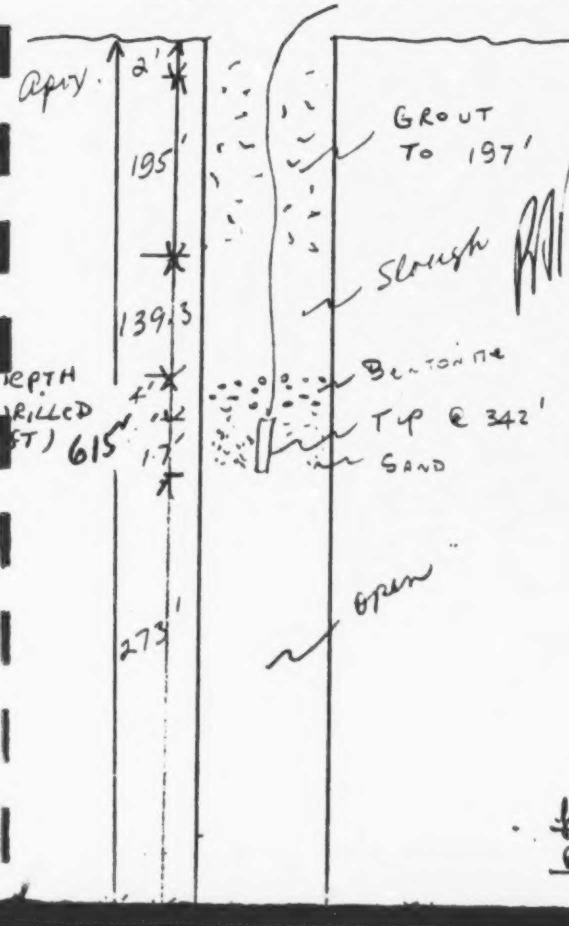
TRANSDUCER SERIAL NO 23405 TOTAL MEASURED LENGTH (FT) 41

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 342

DATE INSTALLED DEC 7/84 DATE GROUTED DEC 10/84

CONSUMABLE QUANITIES Grout 28 Bag Type 50 Cement & 2 Bag Gel
DRILLING - 9 Bags Gel, 3 Bags Revert, 4 Bags Barite

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PS
DEC 7/84	—	153 (BEFORE GROUT)
Dec. 10/84	-	151.5 (BEFORE GROUT)
Mar 8/85		150.5
" 11/85		150.5
Apr 3/85	9:30 AM	150.4

REMARKS. Tip Placed in Canvas Bag 20" long filled with 12-20 Frac Sand, BENTONITE PELLETS RESTRAINED in NETTING & Pantyhose above Sand to 4' [illegible] Grout [illegible] to 197' [illegible]

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Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DA Date ______

TEST HOLE NO P-15

DRILLING STARTED April 9/85 DRILLING FINISHED April 9/85

TYPE OF DRILLING EQUIPMENT CME OPERATOR C.O

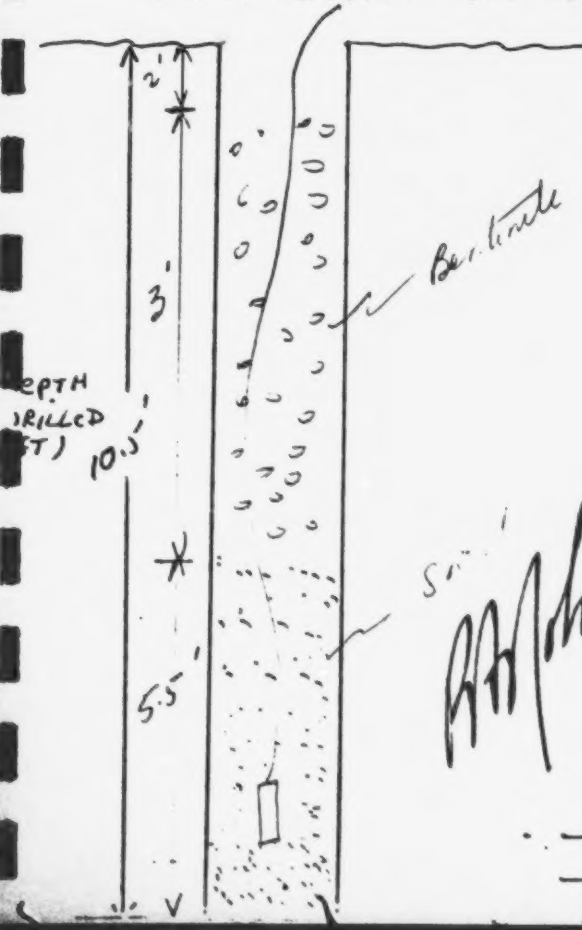
TRANSDUCER SERIAL NO 23051 TOTAL MEASURED LENGTH (FT) 37'

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 7'

DATE INSTALLED April 9/85 @ 6:00 P.M. DATE GROUTED N/A

CONSUMABLE QUANITIES —

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PS
April 10/85	9:05 AM	1.5
" 17/85	11:15 A.M	2.0

REMARKS. Transducer in Bag 20" long. Bentonite Pellets 36" above sand.

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Page ______ of ______
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-16

DRILLING STARTED april 9/85 DRILLING FINISHED april 9/85

TYPE OF DRILLING EQUIPMENT CME OPERATOR C.O

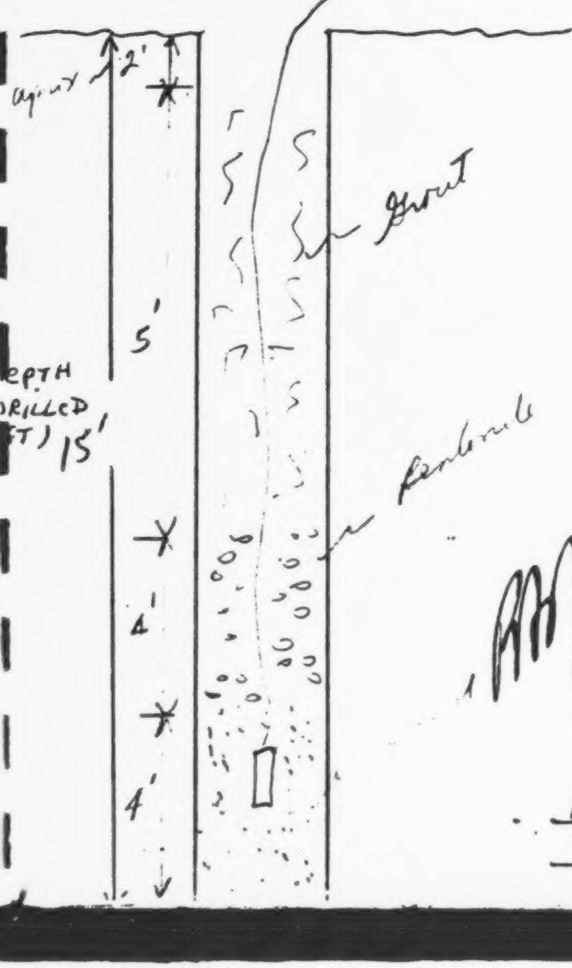
TRANSDUCER SERIAL NO 23057 TOTAL MEASURED LENGTH (FT) 15½

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 13'

DATE INSTALLED April 9/85 @ 5:15 P.M DATE GROUTED april 10/85

CONSUMABLE QUANITIES Grout for P-17 & 13
4 Bags Cement (50) & 1 Gel.

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PSI
April 10/85	8:56 A.M	1.6 B. Grout
✓ 17/85	11:15 AM	4.5 after ✓

REMARKS. Transducer in Bag with Sand 20"
Bentonite Pellets 48" above sand.

Page ______ of ______
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-17

DRILLING STARTED April 9/85 DRILLING FINISHED April 9/85

TYPE OF DRILLING EQUIPMENT CME OPERATOR C.O

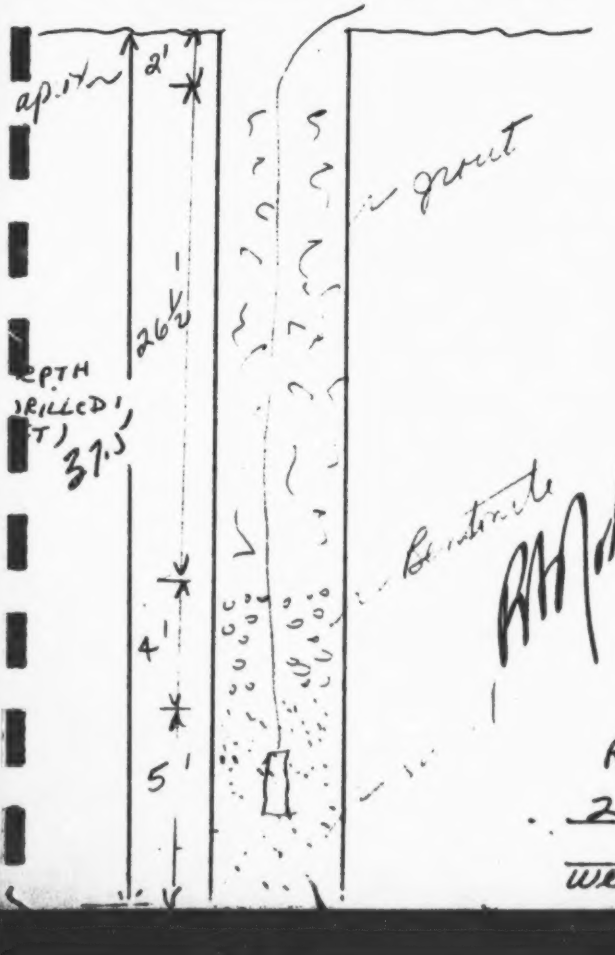
TRANSDUCER SERIAL NO 23053 TOTAL MEASURED LENGTH (ft) 160

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 35'

DATE INSTALLED April 9/85 @ 3:15 P.m DATE GROUTED April 10/85

CONSUMABLE QUANITIES Grout for P-16 & 18
4 Bags cement (50) & 1 Gel.

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READING

DATE	Time	PRESSURE (PSI	
April 10/85	9:10	12.6	B. Grout
" 17/85	11:20 Am	14.1	After Grout

REMARKS. Transducer in Bag with sand 20" long; Bentonite 4' above sand

Weight 15 lbs on Bottom of the Bag.

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BBT GEOTECHNICAL CONSULTANTS LTD.

Page ________ of ________
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ________

TEST HOLE NO P-18

DRILLING STARTED April 9/85 DRILLING FINISHED april 9/85

TYPE OF DRILLING EQUIPMENT CME OPERATOR C.O.

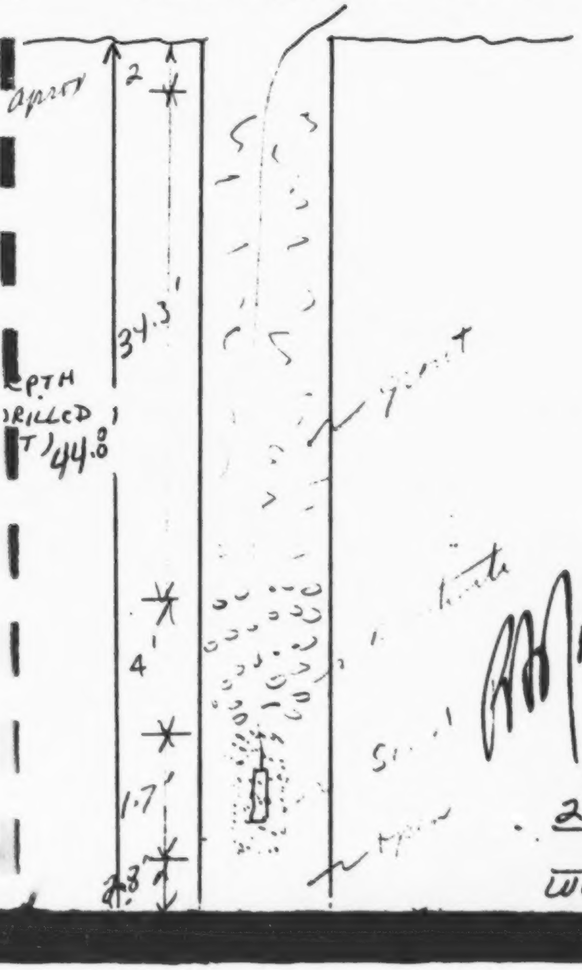
TRANSDUCER SERIAL NO 23055 TOTAL MEASURED LENGTH (FT) 180

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 42

DATE INSTALLED april 9/85 @ 11:15 AM DATE GROUTED april 10/85

CONSUMABLE QUANITIES Grout for P-16 & P-17
Cement 4 Bags & 1 Gel

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READINGS

DATE	TIME	PRESSURE (PSI)	
april 9/85	11:30 AM	0.2	B. Grout
" 10/85	8:20 AM	13.15	" "
" 17/85	11:05 AM	17.1	after Grout

REMARKS. Transducer in Bag with sand 20" long. Bentonite Pellets 48" above sand
Weight: 15" lines on Bottom & 8 Bags.

Page ________ of ________
Job No. S84-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DA Date ________

TEST HOLE NO P-19

DRILLING STARTED April 11/85 DRILLING FINISHED April 12/85

TYPE OF DRILLING EQUIPMENT 1250 Failing OPERATOR D.S.

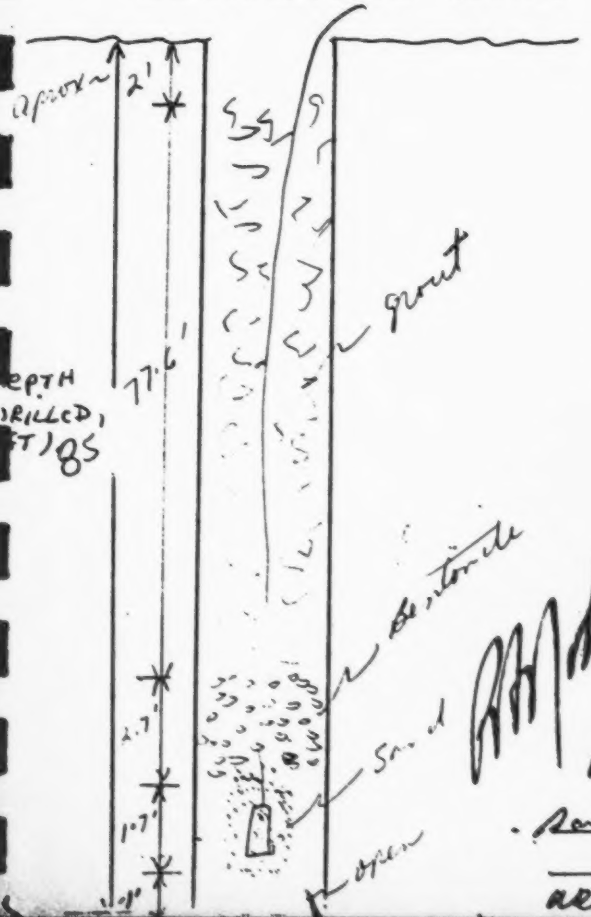
TRANSDUCER SERIAL NO 23059 TOTAL MEASURED LENGTH (FT) 113

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 84.0

DATE INSTALLED April 12/85 @ 12:00 DATE GROUTED April 16/85

CONSUMABLE QUANTITIES Grout - 12 Bags Cement (50)
1 Gel.

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PS	
April 12/85	2:00 P.m	37.5	B. Grout
17/85	11:00 Am	35.1	after

REMARKS. Transducer in Bag 20" long with sand. Bentonite pellets 32" above sand
a weight 15 lbs, on Bottom of Bag.

Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN By DH Date ______

TEST HOLE NO P-20

DRILLING STARTED April 3/85 DRILLING FINISHED April 3/85

TYPE OF DRILLING EQUIPMENT 1250 Failing OPERATOR D. SCHMID

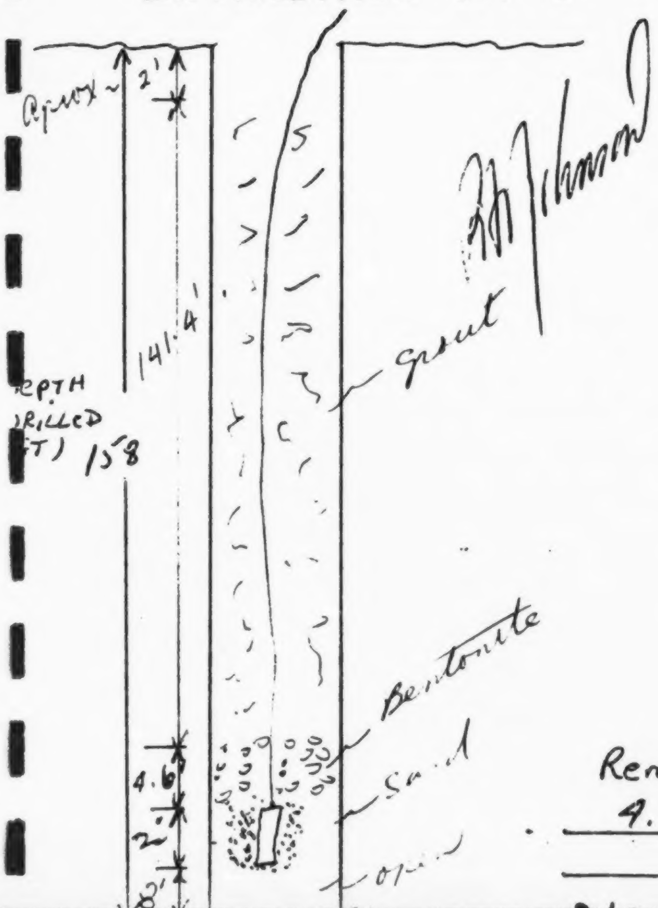
TRANSDUCER SERIAL NO 23065 TOTAL MEASURED LENGTH (FT) 1

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 150

DATE INSTALLED April 3/85 @ 7:00 Pm DATE GROUTED April 4/85

CONSUMABLE QUANITIES Grout - Part of P-21 Batch and 14 Ba
Cement & 1 Gel.

INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READIN

DATE	TIME	PRESSURE (P
April 4/85	8:30 a.m	67.2 B. GROUT
April 10/85	9:15 AM	63.5 after grout

REMARKS. Transducer in Bag with 2' of San
4.6' of Pellets above Bag.

[illegible]

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Page ______ of ______
Job No. 584-1746-1

Project TAILS PILE INSTRUMENTATION
PCS LANIGAN
By DH Date ______

TEST HOLE NO P-21

DRILLING STARTED April 2/85 DRILLING FINISHED April 3/85

TYPE OF DRILLING EQUIPMENT 1250 Failins OPERATOR D. SHMIDT

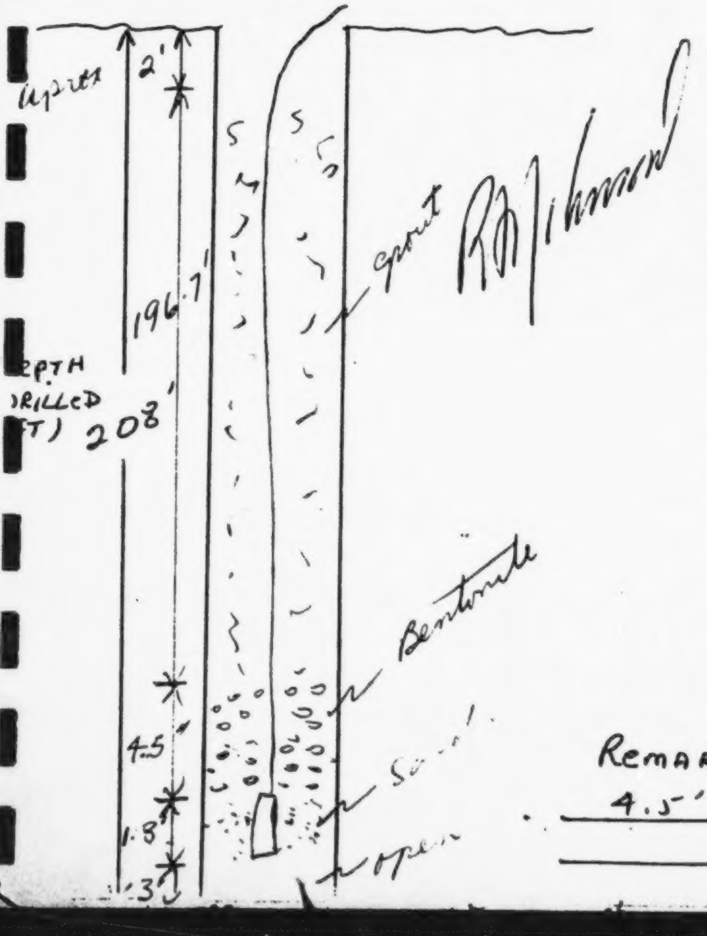
TRANSDUCER SERIAL NO 23049 TOTAL MEASURED LENGTH (FT) 237.

LOCATION OF TRANSDUCER FROM GROUND SURFACE (FT) 205'

DATE INSTALLED April 3/85 @ 12:00 Pm DATE GROUTED April 4/85

CONSUMABLE QUANITIES Grout 24 Bags of type 50 & 2 Bel.

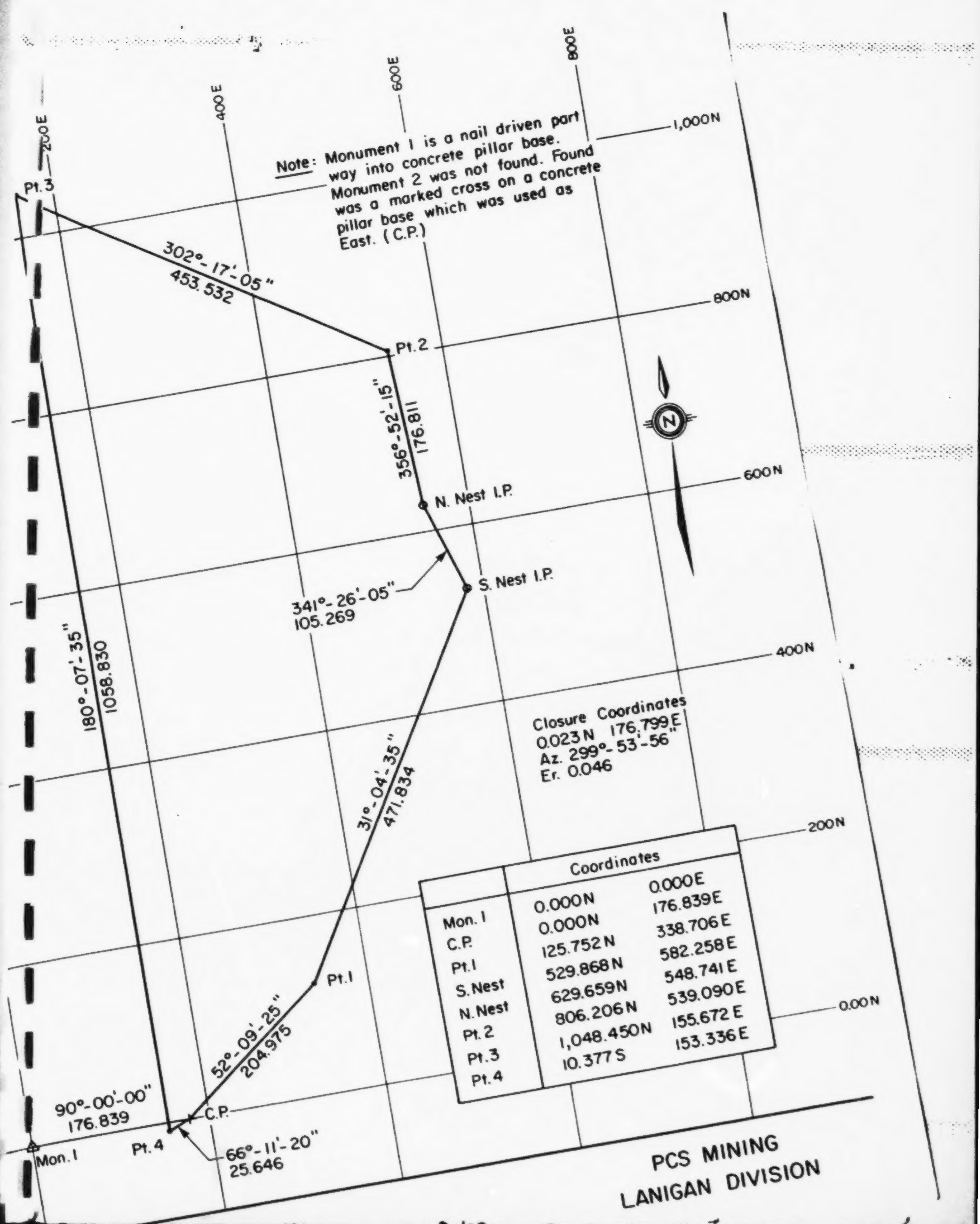
INSTALLATION (N.T.S)



TRANSDUCER PRESSURE READING

DATE	TIME	PRESSURE (PSI
Apr 3/85	2:00 Pm	94 B. Grout
Apr 4/85	8:15 Am	92.3 . B. GROUT.
april 10/85	9.25 Am	89.8 after grout

REMARKS. Transducer in Bag with 1.8' sand
4.5' of Pellets above Bag.

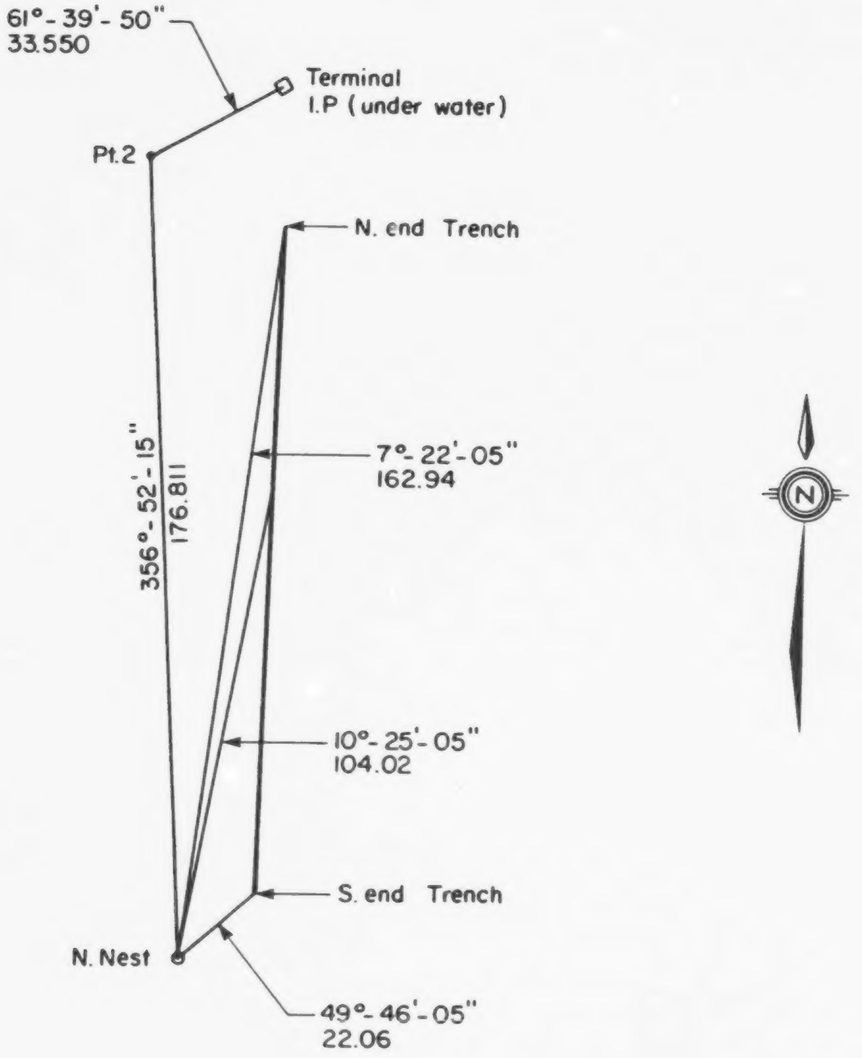

200E
400E
600E
800E
1,000N
800N
600N
400N
200N
0.00N
Pt.3
Pt.2
N. Nest I.P.
S. Nest I.P.
Pt.1
C.P.
Pt.4
Mon.1
N
302°-17'-05"
453.532
356°-52'-15"
176.811
341°-26'-05"
105.269
31°-04'-35"
471.834
52°-09'-25"
204.975
66°-11'-20"
25.646
90°-00'-00"
176.839
180°-07'-35"
1058.830

Note: Monument 1 is a nail driven part way into concrete pillar base. Monument 2 was not found. Found was a marked cross on a concrete pillar base which was used as East. (C.P.)

Closure Coordinates
0.023 N 176.799 E
Az. 299°-53'-56"
Er. 0.046

	Coordinates	
Mon. 1	0.000 N	0.000 E
C.P.	0.000 N	176.839 E
Pt. 1	125.752 N	338.706 E
S. Nest	529.868 N	582.258 E
N. Nest	629.659 N	548.741 E
Pt. 2	806.206 N	539.090 E
Pt. 3	1,048.450 N	155.672 E
Pt. 4	10.377 S	153.336 E

PCS MINING
LANIGAN DIVISION


61°- 39'- 50"
33.550
Terminal
I.P (under water)
Pt.2
N. end Trench
356°- 52'- 15"
176.811
7°- 22'- 05"
162.94
N
10°- 25'- 05"
104.02
S. end Trench
N. Nest
49°- 46'- 05"
22.06

DelCan

TERMINAL & TRENCH DETAIL

Scale 1:150

PCS MINING
LANIGAN DIVISION

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 1

SAMPLE DEPTH 6.2 to 7.2 ft.

CLASSIFICATION Clay - grey brown, v moist, v silty, firm to soft fine sandy

CONFINED FAILURE.

CELL PRESSURE ______ psi

CORRECTED STRESS ______ TSF (____ kpa)

PERCENT STRAIN ______

REMARKS unable to conduct confine test due to soft nature of sample. Free water noted during set up

MOISTURE PERCENT 22.5

DRY UNIT WEIGHT 1.868 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 1

SAMPLE DEPTH 11.5 to 12.0 ft.

CLASSIFICATION CLAY (Till) med brown, moist, stiff, silts, oxides
med plastic, dessicated

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 2.32 TSF (221.9 kpa)

PARCENT STRAIN 20

REMARKS Failure by bulge

MOISTURE PERCENT 15.9

DRY UNIT WEIGHT 1880 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # P4

SAMPLE DEPTH 24.2 to 24.7 ft.

CLASSIFICATION CLAY (Till) dk grey, moist, hard, V sandy with #'s gravel sizes

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 7.2 TSF (687.4 kpa)

PERCENT STRAIN 15.5

REMARKS High % gravel in sample possible GC resulted in very high Dry Density. Failure by Bulge.

MOISTURE PERCENT 9.8

DRY UNIT WEIGHT 2.174 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 5

SAMPLE DEPTH 36.5 to 37.0 ft.

CLASSIFICATION CLAY (Till) med plastic, dk grey, moist
v.stiff, oxides

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 2.04 TSF (195.7 kpa)

PARCENT STRAIN 202

REMARKS Failure by Bulge

MOISTURE PERCENT 149

DRY UNIT WEIGHT 1.918 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 6

SAMPLE DEPTH 47.6 to 48.1 ft.

CLASSIFICATION CLAY-(Till) dk grey, moist, v stiff, med plastic

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 2.88 TSF (275.5 kpa)

PARCENT STRAIN 18.5

REMARKS Failure by Bulge ; Late shear

MOISTURE PERCENT 15.1

DRY UNIT WEIGHT 1.897 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 7

SAMPLE DEPTH 62.5 to 63.0 ft.

CLASSIFICATION CLAY (Till) dk grey, moist, hard, v. sandy
med. low plastic, few shale nuggetts

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 4.40 TSF (421.5 kpa)

PARCENT STRAIN 13.7

REMARKS Failure by Bulge : Shear

MOISTURE PERCENT 14.3

DRY UNIT WEIGHT 1.887 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 8

SAMPLE DEPTH 91.0 to 91.5 ft.

CLASSIFICATION CLAY (Till) dk gray, moist, hard, # gravel sizes
med plastic

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 7.7 TSF (737.6 kpa)

PARCENT STRAIN 12.5

REMARKS Failure by Bulge : Shear

MOISTURE PERCENT 12.8

DRY UNIT WEIGHT 1.919 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 9

SAMPLE DEPTH 105 to 106 ft.

CLASSIFICATION CLAY (Till) dk gray, moist, hard, med plastic

scattered gravel sizes

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 7.96 TSF (761.9 kpa)

PARCENT STRAIN 5.5

REMARKS Failure by shear

MOISTURE PERCENT 13.7

DRY UNIT WEIGHT 1.915 g/cm3

LANAGIAN P.C.S

BBT JOB # SA1746

TEST HOLE # 10

SAMPLE DEPTH 145.5 (44.3m) ~~155.5~~ to 146.0 (44.5m) 156.0 ft.

CLASSIFICATION ClAY (Till) dk. grey moist, hard, sandy, med Plastic

#'s small gravel sizes

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 7.76 TSF (743.4 kpa)

PARCENT STRAIN 6.0

REMARKS Failure by Shear.

MOISTURE PERCENT 15.7

DRY UNIT WEIGHT 1.878 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # P11

SAMPLE DEPTH 206.5 to 207 ft.

CLASSIFICATION Clay (Till) dk grey, moist, hard, shale nuggetts

#'s gravel sizes

CONFINED FAILURE.

CELL PRESSURE 90 psi

CORRECTED STRESS 9.5 TSF (912.9 kpa)

PERCENT STRAIN 11.5

REMARKS Shear : Bulge

MOISTURE PERCENT 14.0

DRY UNIT WEIGHT 1.915 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 12

SAMPLE DEPTH 261.8 to 262.5 ft.

CLASSIFICATION CLAY (Till) dk grey, moist, hard, med plastic

shale nuggetts, gravel sizes

CONFINED FAILURE.

CELL PRESSURE 110 psi

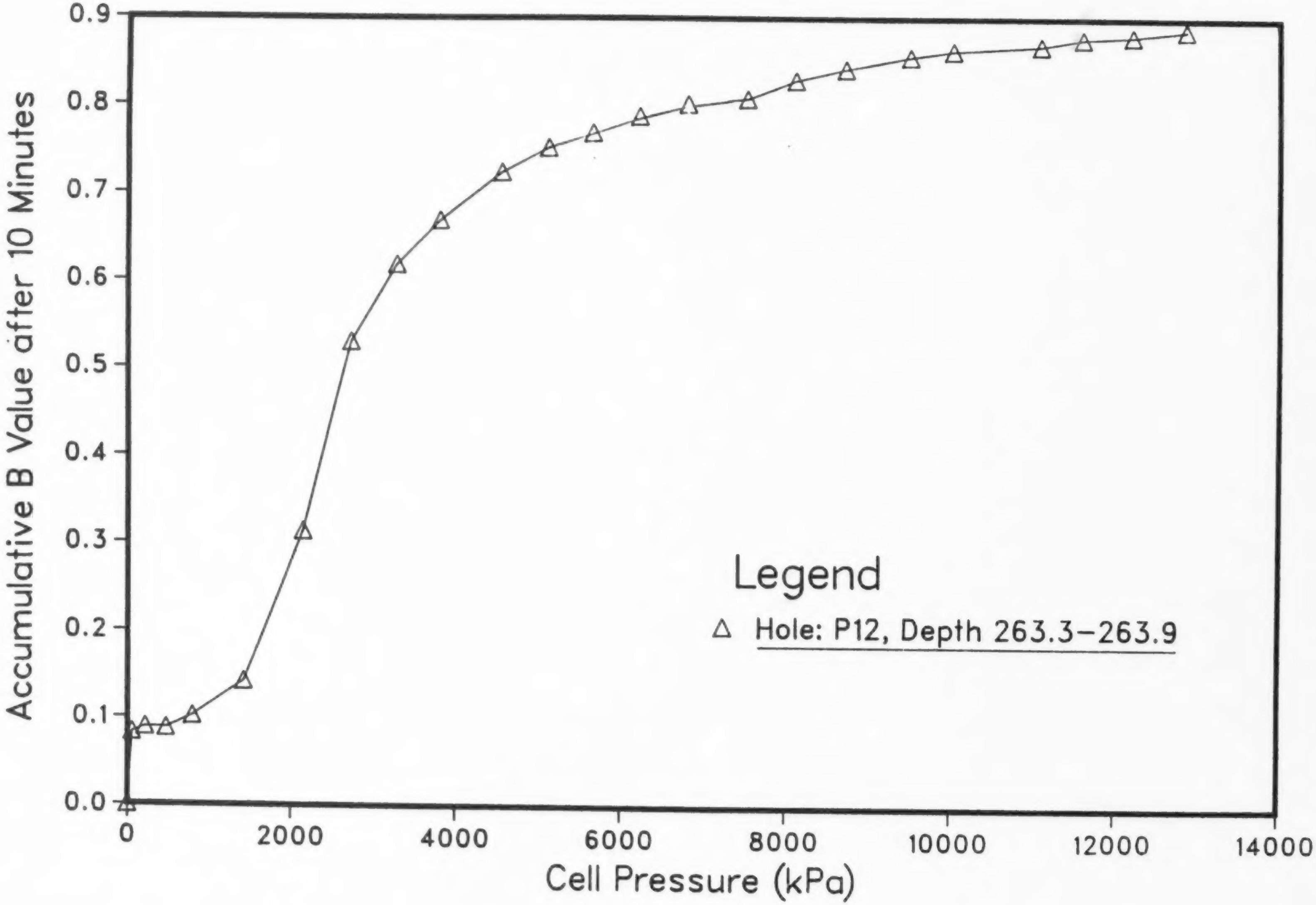
CORRECTED STRESS 6.13 TSF (587.1 kpa)

PARCENT STRAIN 7.5

REMARKS Failure by shear

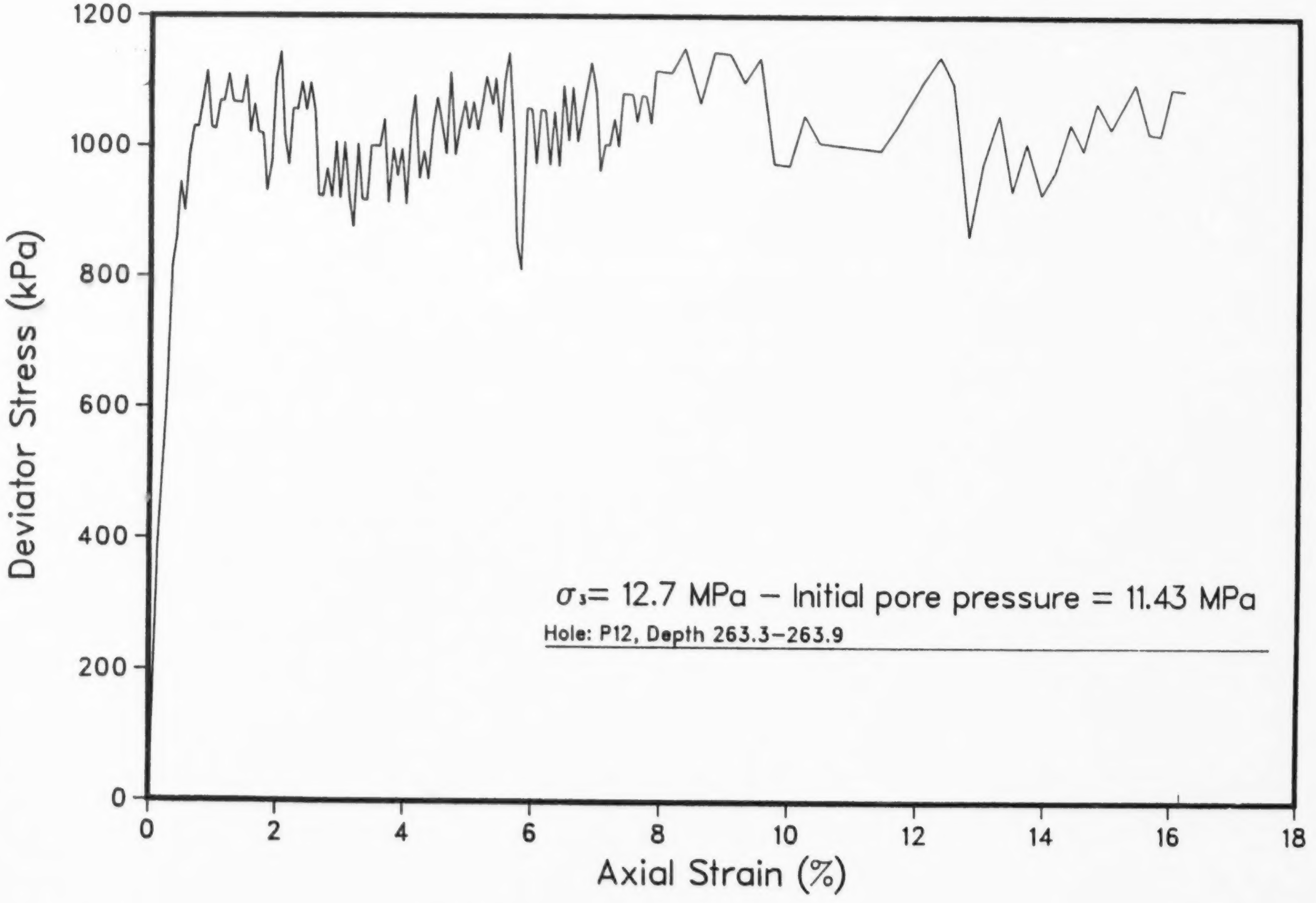
MOISTURE PERCENT 13.8

DRY UNIT WEIGHT 1.954 g/cm3



Cell Pressure vs B Values after 10 minutes for Sample No. 2.

Revision of Dec 11/85



Stress Strain Curve for BBT Sample No. 2.

Rec. Dec 11/85

BBT SAMPLE #2

HOLE: F12
DEPTH: 263.3-263.9

CELL PRESSURE (KPA)	IMMEDIATE PORE PRESSURE RESPONSE (KPA)	PORE PRESSURE AFTER 10 MINUTES (KPA)	ACCUMULATIVE E AFTER 10 MINUTES
0.0	0.0	0.0	0.0
54.5	1.7	4.5	0.08
215.3	8.4	19.2	0.09
472.2	24.1	41.5	0.09
798.1	48.5	81.3	0.10
1426.8	87.6	202.7	0.14
2137.4	223.9	669.7	0.31
2714.1	726.7	1435.0	0.53
3266.7	1509.2	2019.3	0.62
3790.1	2167.3	2535.5	0.67
4539.2	2902.6	3287.4	0.72
5104.2	3566.6	3837.2	0.75
5643.9	4134.3	4342.3	0.77
6208.8	4700.0	4893.8	0.79
6795.9	5321.9	5451.8	0.80
7516.0	6001.8	6071.2	0.81
8105.2	6654.4	6720.0	0.83
8709.0	7264.4	7333.1	0.84
9490.6	8002.4	8121.2	0.86
10010.9	8573.3	8638.8	0.86
11079.9	9442.8	9625.9	0.87
11588.9	10148.6	10164.6	0.88
12197.9	10759.6	10732.6	0.88
12851.9	11168.6	11404.6	0.89

Dec. Dec 11/85

LANAGIAN P.C.S

BBT JOB # SA1746

TEST HOLE # 13

SAMPLE DEPTH 298 to 299 ft.

CLASSIFICATION CLAY (Till) med grey, moist, hard, #'s gravel size
shale chips, med plastic

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 7.8 TSF (742 4 kpa)

PARCENT STRAIN 8.3

REMARKS Failure by Shear

MOISTURE PERCENT 13.2

DRY UNIT WEIGHT 1994 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 15

SAMPLE DEPTH 7.9 to 8.4 ft.

CLASSIFICATION CLAY (Till) med brown, moist, v. stiff, med-low plastic

v. sandy, #'s gravel sizes

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 1.85 TSF (177.2 kpa)

PARCENT STRAIN 20

REMARKS Failure by Bulge

Very difficult to trim due to gravel sizes.

MOISTURE PERCENT 15.2

DRY UNIT WEIGHT 1.881 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 16

SAMPLE DEPTH 11 9 to 13 2 ft.

CLASSIFICATION ClAY (Till) mod plastic, grey brown, hard

salt pockets

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 2.94 TSF (281.6 kpa)

PERCENT STRAIN 20

REMARKS Failure by Bulge

MOISTURE PERCENT 13.7

DRY UNIT WEIGHT 1.966 g/cm3

____ LANAGIAN P.C.S ____

BBT JOB # SA1746

TEST HOLE # 17

SAMPLE DEPTH 33 to 34.7 ft.

CLASSIFICATION CLAY (Till) grey brown, moist, hard

CONFINED FAILURE.

CELL PRESSURE 120 psi

CORRECTED STRESS 3.9 TSF (372 9 kpa)

PERCENT STRAIN 20

REMARKS Failure by Bulge

MOISTURE PERCENT 13.2

DRY UNIT WEIGHT 1.898 g/cm3

____ LANAGIAN P.C.S ____

BBT JOB # SA1746

TEST HOLE # 18

SAMPLE DEPTH 41.3 to 42.7 ft.

CLASSIFICATION CLAY (Till) dk grey, moist, hard, few 2.5cm gravel sizes

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 3.14 TSF (299.9 kpa)

PARCENT STRAIN 20

REMARKS Sample required patching due to removal of gravel sizes during trimming

MOISTURE PERCENT 12.5

DRY UNIT WEIGHT 1.964 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # P19

SAMPLE DEPTH 83.0 to 83.6 ft.

CLASSIFICATION CLAY (Till) gray, damp to moist, hard, oxides

CONFINED FAILURE.

CELL PRESSURE 110 psi

CORRECTED STRESS 7.2 TSF (692.1 kpa)

PARCENT STRAIN 6.0

REMARKS Failed by Shear

Sample Appeared dry i dessicated

MOISTURE PERCENT 11.0

DRY UNIT WEIGHT 1992 g/cm3

___ LANAGIAN P.C.S ___

BBT JOB # SA1746

TEST HOLE # 20

SAMPLE DEPTH 156.5 to 157.5 ft.

CLASSIFICATION ClAY (Till) dk. grey moist, hard, #'s shale nuggetts

CONFINED FAILURE.

CELL PRESSURE 97 psi

CORRECTED STRESS 9.3 TSF (887.6 kpa)

PERCENT STRAIN 4.6

REMARKS Failure by Shear - V band sample

MOISTURE PERCENT 16.5

DRY UNIT WEIGHT 1.898 g/cm3

LANAGIAN P.C.S

BBT JOB # SA1746

TEST HOLE # 21

SAMPLE DEPTH 203 to 203.5 ft.

CLASSIFICATION Clay (Till) dk gray, moist, hard, med plastic

Shale nuggetts ; gravel sizes

CONFINED FAILURE.

CELL PRESSURE 110 psi

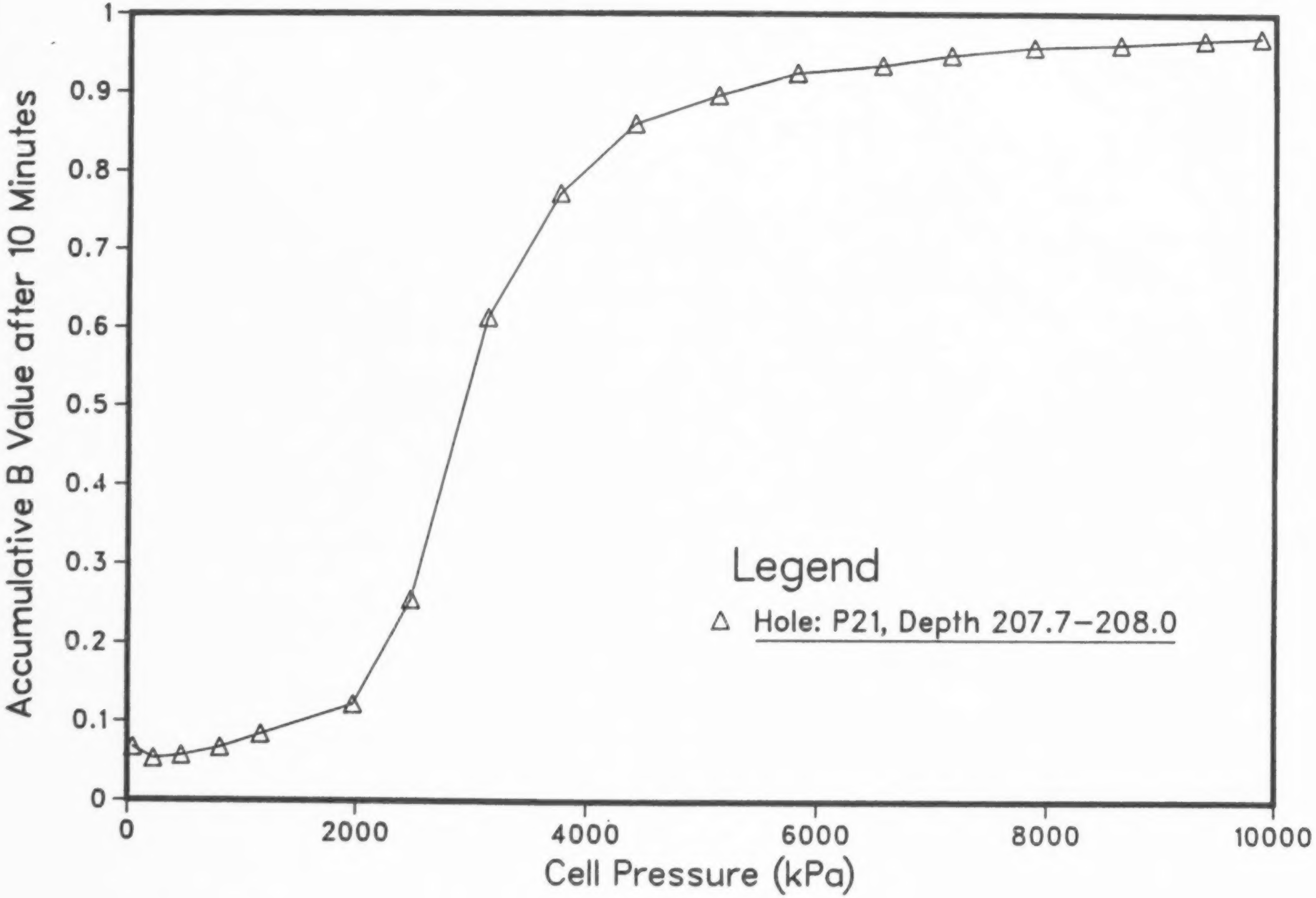
CORRECTED STRESS 4.9 TSF (477.5 kpa)

PARCENT STRAIN 8.9

REMARKS Failure by Bulge ; Shear

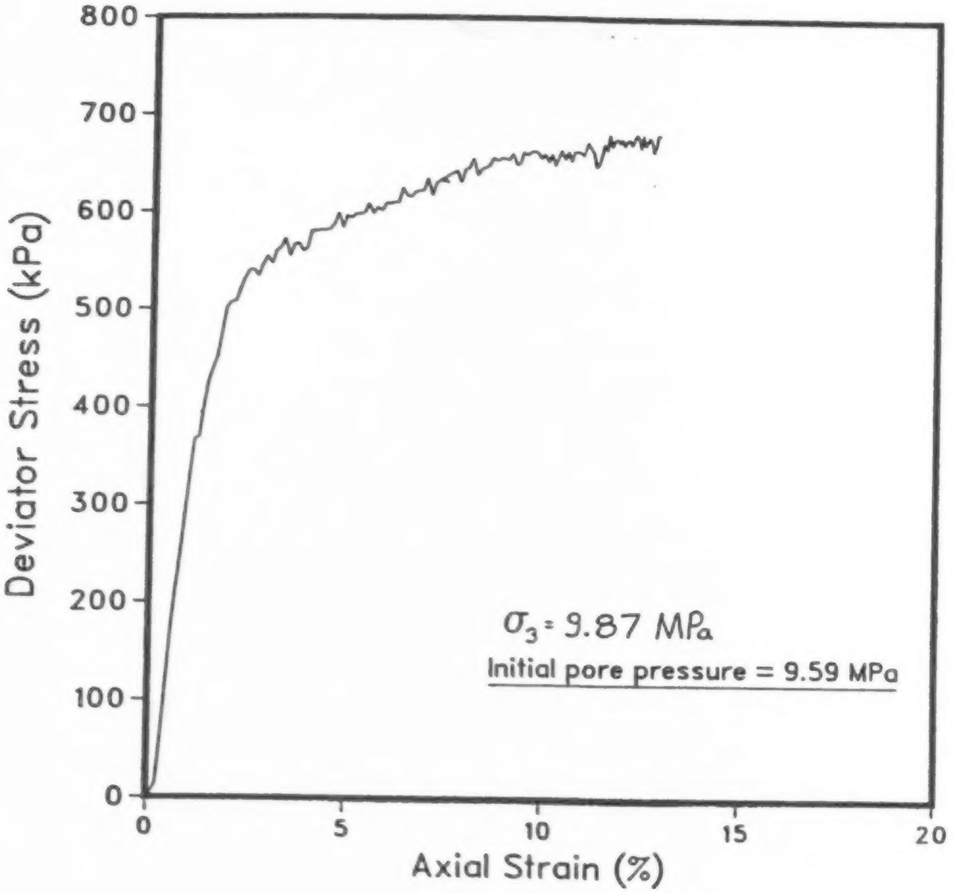
MOISTURE PERCENT 16.9

DRY UNIT WEIGHT 1.862 g/cm3



Cell Pressure vs B Values after 10 minutes for Sample No. 3.

Revision at Dec 11/85



Stress – Strain Curve for BBT Sample No. 3

TEST HOLE: P21

DEPTH: 207.7 – 208.0'

BBT SAMPLE #3

HOLE: P21
DEPTH: 207.7-208.0

CELL PRESSURE (KPA)	IMMEDIATE PORE PRESSURE RESPONSE (KPA)	PORE PRESSURE AFTER 10 MINUTES (KPA)	B AFTER 10 MINUTES
0.0	0.0	0.0	0.0
48.4	1.7	3.2	0.07
226.2	6.3	12.2	0.05
474.3	15.8	27.0	0.06
813.4	31.6	54.2	0.07
1170.8	57.2	98.3	0.08
1976.3	112.4	241.6	0.12
2474.5	257.9	630.5	0.25
3137.6	693.0	1923.6	0.61
3760.1	2203.3	2902.5	0.77
4406.8	3343.4	3791.2	0.86
5129.2	4300.4	4596.2	0.90
5812.4	5127.8	5375.5	0.92
6551.9	5825.4	6126.4	0.94
7151.2	6618.3	6776.2	0.95
7872.1	7319.1	7538.0	0.96
8629.1	8062.3	8305.5	0.96
9371.7	8902.9	9070.7	0.97
9871.8	9507.1	9590.1	0.97

ENVIRONMENTAL AFFAIRS

PCS
Mining

A subsidiary of the Potash Corporation of Saskatchewan

FOUNDATION PORE PRESSURE
UNDER POTASH WASTE PILES

W.C. Long, P. Eng. - Project Engineer
K.N. Lamb, P. Eng. - PCS Mining
J.K. O'Donnell - PCS Mining
March 1986

POTASH CORPORATION OF SASKATCHEWAN MINING LIMITED
ENGINEERING DEPARTMENT
ENVIRONMENTAL AFFAIRS SECTION
Saskatoon, Saskatchewan
Canada

Work on this project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources, Canada under the study title" Pathways Movements of Brine from Potash Tailings at the Potash Corporation of Saskatchewan Tailings Piles in Saskatchewan - Phase 1"

DSS FILE NUMBER : 26SQ.23440-4-9193
DSS CONTRACT : OSQ84-00201
CANMET PROJECT NUMBER : 350107
CANMET SCIENTIFIC AUTHORITY : E.G. Joe

AUG 15 1986
MICROMEDIA

57 pp + 3 figure pages.

March 1986

ID-0717B

ACKNOWLEDGEMENTS

Work on this project was conducted under the auspices of the
Canada Center for Mineral and Energy Technology
Energy, Mines and Resources Canada

PROJECT TEAM
POTASH CORPORATION OF SASKATCHEWAN MINING LIMITED
ENGINEERING DEPARTMENT
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J.K. O'Donnell
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The assistance and co-operation of the Management and Personnel of
PCS MINING, LANIGAN DIVISION and PCS MINING, ROCANVILLE DIVISION
is gratefully acknowledged

TABLE OF CONTENTS

PAGE

EXECUTIVE SUMMARY 1

INTRODUCTION 5

SASKATCHEWAN PLEISTOCENE STRATIGRAPHY 9

THEORETICAL DISCUSSION EFFECT OF LOADING ON BRINE MIGRATION 13

- General 13
- Laboratory Tests 15

CONTRACT LC-7046 PCS MINING, LANIGAN DIVISION 20

- Difficulties and Problems 20
- Stratigraphy 21
- Laboratory Tests and Soil Characteristics 22
- Hydrology 30

CONTRACT M85-3046 PCS MINING, ROCANVILLE DIVISION 32

- Difficulties and Problems 32
- Stratigraphy 35
- Laboratory Tests and Soil Characteristics 36
- Hydrology 43

CONCLUSION 45

BIBLIOGRAPHY 47

APPENDIX A

Report on Installation of Tails Pile Instrumentation for Potash Corporation of Saskatchewan Mining Limited Lanigan Division Phase II Expansion Contract No. LC-7046 - BBT Geotechnical Consultants Ltd. SEPARATE VOLUME

APPENDIX B

Report on Installation of Tails Pile Instrumentation for Potash Corporation of Saskatchewan Mining Limited Rocanville Division Contract No. M85-3046 - BBT Geotechnical Consultants Ltd. SEPARATE VOLUME

TABLES

PAGE

Table 1 Estimation of Preconsolidaton Load Pc Lanigan Division 23

Table 2 Consolidation Characteristics and Permeability Estimates Lanigan Division 24

Table 3 PCS Mining, Lanigan Division Pneumatic Instrument Readings 25

Table 4 Summary of Soil Properties Lanigan Division 26

Table 5 Estimation of Preconsolidation Load Pc Rocanville Division 37

Table 6 Consolidation Characteristics and Permeability Estimates Rocanville Division 38

Table 7 PCS Mining, Rocanville Division Pneumatic Instrument Readings 39

Table 8 Summary of Soil Properties Rocanville Division 40

FIGURES

Figure 1 Soil and Piezometric Profile Lanigan Instrumentation South Site

Figure 2 Soil and Piezometric Profile Lanigan Instrumentation North Site

Figure 3 Soil and Piezometric Profile Site 1A Rocanville Division

Figure 4 Soil and Piezometric Profile Site 2A Rocanville Division

EXECUTIVE SUMMARY

This report plus Appendices summarizes the work and geotechnical data obtained under the Canada Department of Supply and Services Contract OSQ84-00201 with the Potash Corporation of Saskatchewan. To fulfill this contract PCS granted two contracts to BBT Geotechnical Consultants Ltd. to perform the required field work and geotechnical laboratory testing at PCS Mining, Lanigan Division and PCS Mining, Rocanville Division. The work was performed by BBT Geotechnical Consultants during the period November 1984 to December 1985 at a contract price of $324 000. The work undertaken by PCS under Contract OSQ84-00201 is only a preliminary phase of the continuing study "The Effect of Pore Pressures on Deep Migration of Brine from Potash Waste Piles" and will also provide input data for future studies to determine tails pile stability.

The work performed under contract LC7046 at the Lanigan Division consisted of the installation of two nests of geotechnical instrumentation located about 100 metres apart at the site of a proposed extension to the waste tailings pile. The instrumentation was installed in drilled test holes from which soil samples were recovered on which conventional geotechnical laboratory tests were conducted. The south instrumentation nest (Nest 1) consisted of fourteen pneumatic piezometers installed at various depths between 1 and 104 metres to monitor pore pressure changes in the foundation soils while the area was being loaded plus two pneumatic settlement sensors to measure any foundation settlement due to loading. To avoid interference with tails placing and tails pile construction, the pneumatic leads from the instrumentation were extended to a readout station located outside the proposed base of the waste tailings pile on the perimeter containment dike. A 20 metre deep inclinometer casing was installed at the nest to monitor horizontal

movement in the foundation during loading. The instrumentation at the north nest (Nest 2) consisted of seven pneumatic piezometers installed at depths ranging between 1 to 63 metres, and a surface pneumatic settlement sensor with the pneumatic leads extended to the same readout terminal as the south nest. A 20 metre inclinometer installation completed the instrumentation at this nest. Arrangements have been made to periodically monitor the instrumentation while the area is being loaded with tailings.

Pore pressure measurements at Lanigan Division to date indicate that the Empress Group sediments below the waste tailings pile is under artesian pressure with a pressure head 1.7 metres above the ground surface. This natural artesian pressure appears to have restricted the penetration of brine to the top 2 to 3 metres of soil. Test data available indicates that the pressure head in the foundation will probably increase with additional loading.

The work at the Rocanville Division under contract M85-3046 consisted of the installation of two nests of geotechnical instrumentation. Soil mechanics laboratory tests were conducted on the soil samples obtained from some of the bore holes utilized for the piezometers. The lower Site 1A instrumentation package consisted of one pneumatic piezometer installed in the lower part of the waste tailings pile and eight pneumatic piezometers in the underlying foundation at varying depths up to 33 metres to measure pore pressure changes in the foundation due to loading. At Site 1A the pneumatic leads were terminated and the readout installed in a small instrumentation shed located right at the Site. The height of the waste tailings pile at Site 1A was 12 metres at the time the installation was made. The upper nest at Site 2A was located about 500 metres further up the slope of the tails pile at a location where tailings were 31 metres high at the time of the installation. The instrumentation at Site 2A consisted of a pneumatic piezometer near the bottom of the waste tailings pile plus seven pneumatic piezometers in the underlying foundation up to depths of 40 metres into the foundation to measure pore pressure changes. A pneumatic settlement sensor was installed at the base of the waste tailings pile to monitor future foundation settlements at Site 2A. The pneumatic leads from the sensors at Site 2A were extended to the edge of the waste tailings pile and terminated at a readout placed in a small instrumentation shed.

At Rocanville Division the excess head in the underlying foundation soils appears to be between 0.5 and 20 metres which appears to have restricted brine pollution to the top 6 to 7 metres of foundation soils at the upper Site 2A. However, the data obtained to date is inconclusive as to the extent of brine pollution at the lower Site 1A. The large difference between the pore pressures recorded at the Rocanville lower Site 1A and upper Site 2A indicates that fairly substantial pore pressures have built-up in the shale as a result of consolidation due to the load applied by the waste tailings pile.

Realistic predictions of the potential and magnitude of brine flow from the waste tailings piles into the foundation will depend on pore pressure changes in the foundation soils which will only be obtained by monitoring pore pressure changes in the foundation as the waste tailings piles are increased in height. The pore pressure data obtained from the consolidation and shear tests conducted on the soil samples obtained during the investigation is inadequate for this purpose. The data obtained to date supports the preliminary assumption that pore pressure increases due to consolidation of the foundation soils will restrict or prevent the downward movement of brine into the foundation. Arrangements have been completed to periodically monitor and read the instrumentation as the waste tailings pile height increases over the two sites.

Improvements are recommended in future tendering procedures and contract specifications to improve the standard and quality of work performed by contractors as a result of PCS experience with these two contracts.

INTRODUCTION

On August 17, 1984, the Environmental Affairs Section of PCS Mining submitted a research proposal to Canada Department of Supply and Services entitled "Effect of Pore Pressures on Deep Migration of Brine From Potash Waste Piles" to be carried out during the 1984-85 and 1985-86 federal fiscal years. The stated objective of the study was "To determine if pore pressures produced by consolidation of soils beneath a potash tails pile can prevent the deep migration of brine." The proposal for work in the 1984-85 fiscal year was to: "Determine through an extensive deep drilling and sampling program at Rocanville conducted by geotechnical contractors, migration to underlying foundation aquifers and measure the effects on migration due to increased foundation pressure as the tailings pile is raised more than 200 feet above the surface land."

The scope of the 1984-85 work was enlarged to include similar programs at the site of a proposed extension to the Lanigan Division waste tailings pile. PCS Mining promised "A report will be prepared which includes all details on the installation, logs of the pilot holes, all driller's logs, and a tabulation of all data obtained from soil testing and any other relevant information. Using the above data, a summary report will be prepared describing the present extent of brine movement under the tails pile and commenting upon potential for further movement."

PCS Mining Environmental Affairs negotiated two contracts with BBT Geotechnical Consultants Ltd. to perform the desired work envisioned in the August 1984 proposal. Contract LC-7046 covered the work to be performed at the site of Lanigan Division's proposed waste tailings pile extension which included the drilling and electric logging of a pilot hole into the underlying artesian Empress Formation, the installation of 21 pneumatic piezometric sensors at various depths at two different locations plus obtaining soil samples at each piezometer location. The instrumentation also included the installation of three settlement sensors and two twenty metre long inclinometer casings. A readout station was established outside of the proposed pile area to which all the pneumatic leads from the sensors were trenched.

Laboratory testing of the soil samples included percent carbonates, slurry conductivities, consolidation tests, triaxial B pore pressure response tests, and index tests including density, water content and plastic limit determinations. The cost of this work amounted to $138 064. BBT Consultants Ltd. "Report on Installation of Tails Piles Instrumentation for Potash Corporation of Saskatchewan Mining Limited - Lanigan Division Phase II Expansion Contract LC-7046" dated November 7, 1985, appended to this report as Appendix A summarizes the work performed and the data obtained under the contract.

Contract M85-3046 covered the work to be performed at the PCS Mining, Rocanville Division waste tailings pile at two locations on the pile. At the Site 1A location, the work included a pilot hole with electric log drilled into the underlying shale, soil samples from the depth of each piezometric sensor, the installation of eight pneumatic piezometric sensors and the installation of a readout terminal above the piezometric sensors to facilitate the reading of the sensors. The work at Site 2A was similar to the Site 1A work except that only seven piezometric sensors were installed plus a pneumatic settlement sensor at the base of the tails pile. The pneumatic leads from the sensors were trenched to a common point and terminated at the readout installed in a instrumentation shed located on a berm at the edge of the waste tailings pile. Soil mechanics laboratory tests similar to the Lanigan program were conducted on the soil samples recovered at Rocanville. This work plus the summary report cost $155 000. BBT Consultants Ltd. "Report on Installation of Tails Pile Instrumentation for Potash Corporation of Saskatchewan Mining Limited - Rocanville Division Tails Pile Instrumentation Contract M85-3046" dated December 18, 1985, summarizes the work performed and the data obtained under the contract and has been appended to this report as Appendix B.

The scope of the two contracts was limited by financial constraints and the original proposals had to be modified and cut back to tailor the two contracts to the funds available. To stretch the funds as far as possible less expensive but also less precise and more risky installation procedures were tolerated by PCS Mining to enable the contractor to keep the contract costs down. The use of uncased rotary drill holes reduced the contractors ability to place the sensors at the precise depth contemplated, often resulting in filter cavities larger than desirable and sensors that ended up at higher than the proposed elevations. Soil sampling and laboratory testing was also restricted to reduce overall costs.

A review of the available geotechnical data indicates that there is insufficient data to reliably predict the future course of brine migration from the waste tailings pile as the pile increases in height. Reliable predictions will be dependent on accurate pore pressure data which can be obtained by continually monitoring soil foundation pore pressure changes as the height of the waste tailings pile increases.

The original proposal visualized that the work would be completed by December 31, 1984, which proved to be unrealistic since Contract LC-7046 for the Lanigan installation was only awarded October 29, 1984, and Contract M85-3046 for the Rocanville installations was not awarded until February 22, 1985. A revised completion date of June 30, 1985 was negotiated for both contracts. This work was delayed for various reasons with contract completion of Contract LC-7046 in mid November 1985 and Contract M85-3046 in mid December 1985. Inclement winter weather (December 14, 1984 to March 31, 1985) and contractor scheduling of crews postponed or delayed the start of various phases of field work. When work did get underway, the field work for Contract LC-7046 at Lanigan was completed in thirteen working weeks and the field work for Contract M85-3046 at Rocanville was completed in seven working weeks. For both contracts, a time consuming item was the supplementary laboratory geotechnical testing which could not be started until after soil samples were recovered during the field installation of the instrumentation at each location.

SASKATCHEWAN PLEISTOCENE STRATIGRAPHY

Except for the Cypress Hills area, almost all of Southern Saskatchewan has been glaciated and the overburden consists of glacial or Pleistocene deposits overlying bedrock or Empress Group deposits. Four till sheets representing different periods of glaciation have been recognized and traced for hundreds of miles in Southern Saskatchewan. Each of these till sheets were deposited under roughly the same conditions and, except for minor local differences, have similar characteristics and properties. Because of this similarity, if the till sheet can be identified accurately at one location, its behaviour can be predicted based on the results of studies on the same till sheet at a second location often many miles from the site under study. Repetition and omission of beds due to glacial thrusting, gravity faulting and major changes in till thickness tend to confuse identification of individual tills and complicate their correlation.

Based on stratigraphic studies of Pleistocene deposits in Saskatchewan, Christiansen (1968) subdivided the glacial till deposits lying between bedrock or the Empress Group and the present day ground surface into two groups, the lower Sutherland and the upper Saskatoon Group. This differentiation was made on the basis of differences in carbonate content of the tills, electric log resistivity characteristics, and the weathering zone separating the two groups. Christiansen further subdivided the Saskatoon Group into the lower Floral Formation and the upper Battleford Formation and the underlying Sutherland Group was divided into a lower and upper till section. The fault with Christiansen's method of subdivision was that it relied heavily on the analysis of the carbonate content (calcite and dolomite) of the different till sheets. This required X ray diffraction tests which are not readily available in most geotechnical soil mechanics laboratories and cannot be determined in the field.

MacDonald and Sauer (1969) and Hamilton and Tao (1972) both used the initial stratigraphic framework for tills in Saskatchewan established by Christiansen and determined the geotechnical properties of the different tills in an attempt to establish methods to differentiate between the different tills on the basis of differences in geotechnical properties. They determined that measurable differences in geotechnical properties existed between the different till sheets and that the different till sheets could be identified by a combination of these differences and visual inspection.

A detailed discussion of the surficial geology is beyond the scope of this study. Based on the above studies, the pleistocene deposits in Saskatchewan have been subdivided into the following groupings:

SASKATOON GROUP

Surficial Stratified Drift - Lacustrine or alluvial sediments encountered at surface and extending to the Battleford Formation glacial till. May be either sand, silt or clay.

Battleford Formation - Glacial till lying between the stratified drift and the Floral Formation. Comprised of firm, friable, sandy, bouldery, massive unstained glacial till. The base of the formation is commonly marked by a boulder pavement.

Floral Formation - Glacial till lying between the Battleford Formation and the Sutherland Group. The till is generally hard, sandy and highly fractured with manganese and oxide staining along the fracture planes in the zone of oxidation.

SUTHERLAND GROUP

Primarily glacial till lying between the Saskatoon Group and the underlying cretaceous bedrock or Empress Group. The glacial till is typically clayier, more plastic and less dense than the overlying tills of the Saskatoon Group. Also, it is characterized by small particles of cretaceous shale in the soil matrix.

The Empress Group is defined as a group of stratified deposits lying between the bedrock surface and the Sutherland Group and is composed of a mix of gravel, sand, silt, clay and till. The Empress Group may range up to 30 metres thick. The Empress Group is generally considered to be of pre-glacial origin and may be correlative with the non glaciated Cypress Hills gravels in southwest Saskatchewan and the so called Saskatchewan gravels in south and central Alberta. Most pre-glacial buried valleys appear to be infilled with Empress Group sediments.

The Sutherland Group comprising a lower and upper till is composed of till and stratified drift ranging in thickness up to 85 metres. The tills are dense, gray, hard and are less electrically resistive and more clayey than tills of the Saskatoon group. Both the calcite and dolomite content of the carbonates in the till range from 2% in the upper part of the till to from 2% to 6% in the lower till in the group. Typical range of physical properties are a liquid limit of the order of 35 to 50 with a plasticity index of about 20 to 30, a dry density of about 1 800 kg/m^3 and water contents around 10 to 15%. The top of the Sutherland Group is often marked by a weathered zone or stratified drift.

The Saskatoon Group has been defined as comprising all sediments lying between the Sutherland Group and the present day ground surface. This group ranges up to 115 metres thick and is composed of till and stratified drift. The calcite content of the tills ranges between 4 to 6% while the dolomite content range is from 8 to over 20%. The Saskatoon Group tills comprising the Battleford and Floral Formations, are sandier, have higher resistivity values and contain less clay and are less plastic than the tills in the Sutherland Group.

The Floral Formation till lying between the Sutherland Group and the upper Battleford Formation, ranges up to 50 metres thick and is composed of till with sand and gravel interbeds. The till is hard, fissured, heavily stained on weathered joint surfaces and generally is more silty than the tills in the Sutherland Group and less sandy than the tills of the Battleford Formation. The upper part of the Floral Formation is commonly oxidized, jointed and stained. Typical physical properties are a liquid limit around 30 to 35 with a plasticity index of 15 to 20, a dry density of 1 700 to 2 000 kg/m^3 and water contents around 13%. Unoxidized Floral till has a compression index around 0.14 and a preconsolidation pressure of 700 to 900 kPa.

The Battleford Formation ranges up to 50 metres thick but is commonly less than 3 metres thick and the base is commonly marked by a solid and striated boulder pavement. The till of the Battleford Formation is soft, friable, bouldery and unstained with a high dolomite content. Typical physical properties are a liquid limit less than 30 with a low plasticity index of 10 to 15, a dry density of 1 700 to 2 000 kg/m^3 and water contents of 9 to 12%. Unoxidized Battleford till has a compression index around 0.06 to 0.17 and a preconsolidation pressure of 200 to 450 kPa.

Both the Lanigan and Rocanville waste tailings piles are situated near or over infilled preglacial valleys which are generally infilled with Empress Group deposits. In or adjacent to these valleys it is quite possible that due to collapse, sliding, erosion or ice thrusting some repetition of till strata has occurred in the valley sediments. Extensive geotechnical investigation would be required to confirm or disapprove the occurrence of these types of geological anomalies.

THEORETICAL DISCUSSION EFFECT OF LOADING ON BRINE MIGRATION

General

When the total stress within a hydrogeological system changes, the pore pressures within the system will change due to partitioning of the stress change between the pore fluid and the solid soil skeleton and may have important effects on ground water flow patterns. At both mine sites the emplacement of additional solid waste could increase the hydraulic head in the saturated aquitard forming part of the foundation.

Normally loaded soils subject to loading will gradually consolidate as the applied load continues to increase. In saturated soils the extra load is first carried by the pore water, which temporarily increases the pore water pressure. Over time the pore water pressure gradually decreases as the pore water drains from the soil and the excess load is gradually transferred to the soil skeleton. The consolidation process results in a temporary excess head which is greatest at the centre of the aquitard and may be large enough to act as a hydro-dynamic barrier to the downward movement of contaminants from the waste tailings containment area. Continuous loading will maintain an excess pore pressure but after loading stops the excess head will dissipate due to drainage and the hydrodynamic barrier will eventually disappear. However, in the course of the consolidation process the vertical hydraulic conductivity of the aquitard may be considerably reduced thus permanently lessening the rate of flow and potential for brine transport through the aquitard. For low permeability soils dissipation of excess pore pressure could take years or even centuries for complete dissipation to occur.

The glacial clay aquitards underlying the two waste tailings piles are overconsolidated as a result of glaciation and will not react like a normally consolidated soil until the applied load is greater than the preconsolidation pressure or load which the soil has been subjected to sometime in its past geological history. With the melting of the glaciers unloading of the underlying foundation soils took place with the result that the existing overburden load is now much less than the preconsolidation load or pressure. Subsequent to this unloading over a period of time, a certain amount of rebound or expansion may have occurred resulting in a small volume increase to the overconsolidated soils. When the soil is reloaded two things will occur - first recompression will take place to counteract the effects of this rebound, and secondly, after sufficient additional load is applied to exceed the preconsolidation load the soil will react and consolidate in a manner similar to a normally consolidated soil. During the recompression phase, soil pore pressures will build-up gradually in relation to the applied load with much of the stress being taken up by the prestressed soil skeleton, however, after the preconsolidation load is reached, assuming no or only minimal drainage, the magnitude of pore pressure increase will roughly equal the additional applied load.

Other factors which will have an effect on overall pore pressure build-up are the thickness and permeability of the foundation soils which will affect the rate of drainage and dissipation of pore pressure and the rate of tails pile loading. The presence of even small continuous hydraulically connected more permeable horizons or sand layers in the till mass will enhance drainage allowing pore pressure to dissipate more rapidly. A slow loading rate would allow sufficient time for most of the pore pressure build-up to dissipate between load increments, whereas with rapid loading, little or no dissipation would take place.

For a load of large aerial extent in relationship to height such as a waste tailings pile, the effective vertical stress applied to the foundation soils will decrease only slightly with depth in accordance with elastic theory.

Initially during the construction of a tailings pile with the usual slow rate of loading of about ten feet or less a year, and while the overconsolidated foundation soils are in the recompression phase, there will likely be only a small overall build-up in pore pressures since there is sufficient time for the pore pressures to dissipate. However, with a rapid rate of loading and/or the foundation soils in the consolidation phase a much more rapid pore pressure build-up will take place, which may take years to dissipate.

Another factor that could have a big effect on the pore pressure in the foundation soils is the pore pressure changes that occur in the aquifer in the underlying more pervious Empress Group. A change in the hydraulic pressure in the aquifers in the Empress Group will affect the pore pressure in the overlying aquitards. The waste tailings pile at Rocanville is located near, while the pile at Lanigan is located over infilled preglacial valleys containing Empress aquifers which are affected by environmental and man induced changes remote from both mine sites. A decrease in these aquifer hydraulic pressures would increase the potential for pore pressure dissipation, while an increase in the aquifer pressures would slow down drainage and decrease the potential for pore pressure dissipation.

Laboratory Tests

In addition to conventional soil mechanics laboratory index tests used primarily for stratigraphic identification purposes, a limited number of physical tests were conducted in an attempt to predict the pore pressure build-up in the foundation soils. The physical tests conducted consisted of consolidation and triaxial $\overline{B}$ pore pressure response tests.

From the consolidation test, it was hoped to obtain information from which the settlement that would occur due to loading could be computed, and the preconsolidation pressure or load which the soil had been subjected to in its past geological history determined. At loads greater than the preconsolidation stress it was believed that the pore pressures would increase almost directly with the applied load, whereas at loads less than this stress value during the recompression phase, the pore pressure increase would not be as great. Plots showing the results of consolidation tests at the Lanigan and Rocanville sites are included in Appendices A and B respectively. Unfortunately due to load limitations of the testing equipment, the maximum loading used was only 1 600 kPa at Lanigan and 3 200 kPa at Rocanville. These loads were likely not adequate to determine the preconsolidation pressure in the over-consolidated glacial clays at Lanigan, and also possibly at Rocanville. MacDonald and Sauer (1969) used 120 tsf and Hamilton and Tao (1972) used 50 tsf for their consolidation tests on glacial tills in the Saskatoon and Blackstrap areas. Because of the limited load the consolidation tests generally show only the recompression phase and the preconsolidation load and compressive index cannot be determined with certainty.

Detailed laboratory testing data for the consolidation tests has been obtained from BBT Geotechnical Consultants Ltd. If required, this data is on file at PCS Mining, Environmental Affairs Section, Saskatoon, in their files TEL-TAD-0006 and TER-TAD-0006 for the Lanigan and Rocanville sites respectively. Only summary sheets and plots for the consolidation test results are included in the respective Appendices.

Triaxial $\overline{B}$ pore pressure response tests were conducted to determine the pore pressure build-up in a soil specimen with no drainage upon the application of an all around confining pressure. In this test, a sample of the natural soil is set up in a triaxial test apparatus and the confining pressure is increased in increments and pore pressure measurements taken until the rate of pore pressure increase equals the confining pressure increase. When the response test was completed, the sample was failed by the application of a vertical load which is an unconsolidated undrained test to determine the shear strength. The initial stages of this test are similar to the recompression phase in the consolidation test, and it would normally be expected that only a small increase in pore pressure would take place during the initial application of the confining pressure, followed by a phase in which the increase in confining pressure would equal the increase in pore pressure. If the sample is saturated the intercept of the straight line portion of the pore pressure line when the pore pressure equals zero should represent a pressure to which the soil can be loaded without a significant increase in pore pressure. This should roughly correspond to the pressure intercept of the zero void ratio line with the compression index Cc in a consolidation test e-log p plot as both essentially represent no volume change conditions. The load up to this point is supported by the soil skeleton, and assuming idealized conditions, this should be the load which can be applied without an appreciable pore pressure increase. Once this loading is reached or exceeded, the pore pressure increase under no drainage conditions would be expected to equal the applied load.

Plots of the triaxial $\overline{B}$ response test results are given in Appendices 1 and 2 for the Lanigan and Rocanville sites respectively. The triaxial $\overline{B}$ response test results obtained were not quite what was expected. Two tests, P12 and P21 at Lanigan, were conducted by the University of Alberta using confining pressure loads of from 10 to 12 000 kPa and the test results were about what would be expected in overconsolidated glacial clay soils. BBT Geotechnical Consultants did comparison tests and all the remaining tests in their own soil mechanics laboratory in Edmonton. However, due to equipment limitations the maximum load which BBT could apply was between 700 and 800 kPa which was not a high enough load in some of the tests to develop a good pore pressure response plot. In addition, some of the test results gave what appears to be erratic results with the pore pressure increasing right from the initial loading almost linearly with the applied confining pressure. Discussing this anomaly with the Consultant, it appears that the soil samples were recovered in the field by conventional coring methods and placed in a plastic sleeve liner. They were then transported to Saskatoon where after a time interval varying from several days to weeks, the samples were examined and the core logged. During this visual examination of the samples it was noted that the samples had dried out to varying degrees and that there were fissures in the samples. The samples were then waxed and sent to Edmonton for testing. During the testing a small back pressure was applied to saturate the sample, and the sample was allowed to drain under a small confining pressure. During this saturation procedure, it is conjectured that water may have got into fissures in the soil sample being tested and this excess water resulted in the almost immediate pore pressure response obtained in some of the tests.

In conclusion, some of the results of the physical testing conducted may not be reliable or representative of insitu conditions due to equipment load limitations and possible sample deterioration prior to testing. The results should be used with caution. The actual consolidation test plots can likely be used within the load limitations to predict settlement behaviour but not to estimate the preconsolidation load or compressive index. The triaxial $\overline{B}$ tests are suspect throughout and although some tests appear to give about the results that would be expected up to the confining pressure or load limitation, the load was not sufficient to adequately define the pore pressure response. The shear tests obtained by failing the soil specimen after the response test was completed may not be representative of the unconsolidated undrained shear strength of the insitu foundation soils due to drying out of the soil samples prior to testing. If the samples were dried out, the tests would give higher strength values than actually exist in the foundation soils.

Because of these possible limitations on the physical testing conducted, the use of empirical correlations based on soil mechanics index tests, should be used to estimate the soil parameters, and the results of studies conducted by others on similar glacial clays at other sites checked and compared. If the results of the actual physical testing are in essential agreement with the empirical correlations or results of others, then the results are likely valid. However, if they disagree, the results obtained from the empirical methods or obtained by others should be used in preference and are more likely to portray realistic insitu conditions in order to predict the behaviour of the insitu soils at both Lanigan and Rocanville.

Difficulties and Problems

The contractors work progress is summarized in "Table 1-Schedule of Work Activities" page 2 of the contractors report in Appendix A. In Section 2.3.5 page 9 under "Installation Difficulties" the contractor lists cold weather, wet spring ground conditions, and problems with the first two installations due to insufficient clearance in the drill hole for the piezometer assembly.

The shallow piezometer installations, using a hollow stem auger to advance the bore hole resulted in a higher quality of installation than the deeper uncased rotary drilled holes. In the ten holes drilled with the auger, the piezometric sensor was placed at the desired elevation but in the twelve holes drilled by the rotary method only two piezometric sensors landed at the design depth leaving a void of varying length below the sensing element. Section 2.3.2 page 7, Appendix A of the contractors report describes the two types of installation used. Details of individual installations are included in Section 8 of Appendix A as part of the contractors report. The installation technique used in some of the auger holes probably would not have been that successful in the deeper rotary drilled holes where sensor, filter and bentonite seal were installed as a unit instead of separately as in the auger holes because of hole sluffing or caving which would interfere with the installation procedure. The pore pressure indicated by a piezometric sensor located at the top of an open cavity may not be representative of the pore pressure in the soil at the sensor elevation. The reading obtained from the sensor may be reading the pore pressure opposite the open cavity which could be either higher or lower than at the sensor location or could be measuring an average of the open cavity pressure.

The bentonite pellets used to seal the hole above or below the sensor absorb water very quickly and in a matter of a few minutes swelled sufficiently to fill the hole. This allowed very little time to adjust the depth of the sensor when for one reason or another, the sensor hung up in the hole above the targeted depth. BBT Geotechnical Consultants found that it was impossible to pull the sensor assembly back after the bentonite pellets had been exposed for only a few minutes to fluid in the hole as the pellets quickly started to swell.

Stratigraphy

Figures 1 and 2 summarize pertinent geological and geotechnical data at the south and north instrumentation sites respectively. The stratigraphy and test hole log is based on BBT Geotechnical Consultants Ltd., pilot hole log for test hole P14 (plans 584-1746-20 to 27 inclusive) drilled at the south instrumentation nest. This basic test hole log has been modified and the site geology interpreted from an examination of rotary drill cuttings, drill reaction, electric logs and core barrel soil samples obtained from proposed sensor elevations and soil mechanics laboratory index test results. The test results from the laboratory testing and the position of the installed piezometers have been added to complete the plots. In addition, typical piezometric levels plotted to a relative scale obtained from monitoring the piezometers in September and November 1985 are shown.

The waste tailings pile is situated over the pre-glacial Hatfield Valley which was infilled with glacial sediments during four succeeding glaciations. Four tills, subdivided into two groups, are recognized in Saskatchewan with the break between the two groups determined by the differences in resistivity characteristics, carbonate content and the amount of clay (plasticity characteristics).

The underlying Sutherland Till Group at the Lanigan site overlies the Empress Group which is a stratified mix of gravel, sand, silt and clay. The hole depth between 67 and 181 metres has been logged from rotary cuttings as alternate deposits of sand-gravel and till and the information is inconclusive as to whether this depth interval penetrates the Sutherland or the Empress Group. Determination of the correct geological setting is necessary to indicate whether the porous deposits are isolated pockets or interconnected aquifers as this fact will impact on the predicted hydrological flow. The geotechnical data available indicates that the depth interval between 28 metres and 67 metres probably represents the Sutherland Till Group based on liquid limits over 40, the sudden change in resistivity and the carbonate content of 5.5%.

The interval between 2 and 28 metres appears to conform to Christiansen's criteria for the Saskatoon Group. Insufficient geotechnical information is available to confidently subdivide this interval into the Floral and Battleford formations however, based on the difference in liquid limits, the break between the two formations could occur between eight and ten metres.

Laboratory Tests and Soil Characteristics

The soil mechanics laboratory tests conducted consisted of index tests such as water content, density, grain size determination and Atterberg limit tests at the location of each piezometer sensor. In addition, physical tests consisting of consolidation tests and B pore pressure response tests were conducted. Slurry conductivity tests and carbonate analyses were carried out on a limited number of samples from selected locations. The results of these tests are summarized in tabular form in Table 4.

TABLE I ESTIMATION OF PRECONSOLIDATION LOAD P_c - LANIGAN DIVISION

1. Assumptions - Saturated soil 1 162 kg/m^3, drained tailings 1 600 kg/m^3, unsaturated soil 2 163 kg/m^3.
2. Water Level Elevation - 530.5 meters Ground Elevation - 531.5 meters.
3. Empirical Formula for Pc - $Pc = \frac{1\ 532}{10^e}$ for overburden in kPa where e is initial void ratio.
4. Peck's Ratio - Undrained shear strength to effective normal pressure and the plasticity index Su/P = .11 + .0037 Ip.
5. Navfac (1961) Ratio - Su/P = 0.25 for low plastic clays and 0.35 for highly plastic clays.
6. Conversion Factor - 1 kPa ≠ 100 kg/m^2.

Formation	Sample	Depth m	Present Load kg/m^2	Empirical Check Values Pc (kPa)						Test Results Pc (kPa)			
				e_o	#3 Pc Empirical	Ip	Su kPa	#4 Pc Peck	#5 Pc Navfac	Pc* Casagrande min	Pc* Casagrande max	Pc* Navfacs Const.	Pc* Formation Estimate
Silt	1	2.1	3 441	.706	301	5				36	47	47	43* (300)
Battleford	2	3.6	5 184	.498	487	11	111	736	444	160	260	200	150 (555)
	3	4.4	6 114	.493	492					75	105	90	
	4	7.4	9 600	.296	775	8	344	2 464	1 376	240	400	400	
	15	2.5	3 906	.519	464	14	89	547	356	70	80	100	
	16	3.8	5 417	.440	556	16	144	851	576	180	280	200	
Floral	5	11.3	14 132	.512	471	20	98	533	392	100	150	130	190 (532)
	6	14.5	17 850	.489	497	16	138	816	552	160	200	200	
	7	19.2	23 311	.480	507	13	211	1 335	844	100	280	260	
	8	27.8	33 277	.377	643	16	369	2 181	1 475	320	420	350	
	9	32.2	38 417	.465	525	15	381	2 302	1 524	200	400	300	
	17	10.3	12 970	.437	560	16	187	1 105	748	130	170	170	
	18	12.7	15 758	.460	531	18	150	849	600	90	150	150	
	19	25.4	30 516	.464	526	19	346	1 919	1 384	270	320	270	
Sutherland	10	47.5	56 196	.426	574	23	372	1 907	1 488	310	400	350	360 (550)
	11	63.0	74 207	.437	560	26	457	2 216	1 828	240	300	240	
	20	47.9	56 661	.469	520	23	444	2 276	1 776	350	480	400	
	21	61.9	72 929	.447	547	28	239	1 119	956	240	300	240	
	21	63.4	74 672	---	---	23	325	1 666	1 300		---	---	
Empress	12	79.9	93 845	.398	613	12	234	1 904	840	250	300	310	440 (577)
	12	80.4	94 426	---	---	15	635	3 857	1 814	---	---		
	13	91.1	106 859	.443	541	17	371	2 106	1 060	420	600	460	

Note - * Pc values listed are based on e-log p plot interpretation using Casagrande and Navfac methods. These results may be too low as the maximum loading used in the consolidation test was only 1 600 kPa, which may not have been sufficient to define the compressive index C_c and determine the Pc. For comparison purposes the average Pc value obtained from the empirical

TABLE 2 CONSOLIDATION CHARACTERISTICS AND PERMEABILITY ESTIMATES - LANIGAN DIVISION

1. Void Ratio - e_o initial, e_f = final.
2. Coefficient of Compressibility $a_v = e_o - e_1/P_1 - P_0$ cm^2/gm.
3. Coefficient of Consolidation $c_v = 0.197\ H^2/t50$ cm^2/sec or $0.848\ H^2/t90$.
4. Coefficient of Volume Compression $m_v = a_v/1 + e$ cm^2/gm.
5. Compressive Index $C_c = e_o - e_1/\log P_1 \div P_0$. Values for glacial clays usually fall in range of 0.1 to 0.2.
6. Permeability - $k = c_v \cdot \gamma w \cdot a_v / 1 + e$ cm/sec.

Note: Consolidation tests may not have reached straight line portion of e-log P curve at maximum load used of 1 600 kPa.

ITEM		1	1	2	3	4	5	6	6
Formation	Sample	e_o	e_f	av $\times 10^{-6}$ cm^2/gm	c_v $\times 10^{-3}$ cm^2/sec	m_v $\times 10^{-6}$ cm^2/gm	Cc	k $\times 10^{-9}$ cm/sec	k average cm/sec
Silt	1	0.706	0.545	10.7	3.87	0.64	0.101	17	1.7×10^{-8}
Battleford	2	0.498	0.322	12.2	0.19	8.2	0.176	1.5	1.1×10^{-8}
	3	0.493	0.330	10.8	1.28	7.2	0.138	9.4	
	4	0.296	0.239	4.2	3.26	3.4	0.069	10.5	
	15	0.519	0.336	12.0	2.85	8.1	0.135	22.4	
	16	0.440	0.308	9.3	1.79	6.8	0.139	11.8	
Floral	5	0.512	0.360	10.1	0.53	7.3	0.126	3.8	6.1×10^{-9}
	6	0.489	0.367	8.5	1.33	6.2	0.122	7.8	
	7	0.480	0.373	8.3	1.27	6.0	0.124	7.4	
	8	0.377	0.360	10.0	2.49	0.97	0.100	1.8	
	9	0.465	0.376	6.9	2.75	4.9	0.122	14.0	
	17	0.437	0.334	7.0	0.51	4.7	0.094	2.4	
	18	0.460	0.345	7.7	0.57	5.3	0.096	3.2	
	19	0.464	0.368	7.2	1.59	5.3	0.122	8.1	
Sutherland	10	0.462	0.358	4.9	1.27	3.6	0.097	4.7	4.3×10^{-9}
	11	0.437	0.375	4.6	0.52	3.2	0.075	6.1	
	20	0.469	0.396	5.9	1.24	4.3	0.113	5.4	
	21	0.447	0.362	6.3	0.21	4.6	0.103	0.9	
Empress	12	0.398	0.317	6.0	1.27	4.3	0.103	5.5	2.9×10^{-9}
	13	0.452	0.354	8.4	6.19	6.2	0.120	0.4	

TABLE 3 PCS MINING, LANIGAN DIVISION PNEUMATIC INSTRUMENT READINGS

Formation	Tip No.	Ref. Elev. E Metres	Date: June 26, 1985			Date: September 17, 1985			Date: November 13-14,1985			Date:			Date:		
			Read R PSI	X.704R Head-H Metres	H + E Elev. Metres	Read R PSI	X.704R Head-H Metres	H + E Elev. Metres	Read R PSI	X.704R Head-H Metres	H + E Elev. Metres	Read R PSI	X.704R Head-H Metres	H + E Elev. Metres	Read R PSI	X.704R Head-H Metres	H + E Elev. Metres
Alluvial	P1	530.37	0.5	0.35	530.72	1.0	0.70	531.07	2.5	1.76	532.13						
Oxidized	P2	529.57	1.8	1.27	530.84	2.3	1.62	531.19	3.7	2.60	532.17						
Till	P3	527.91	5.1	3.59	531.50	5.1	3.59	531.50	7.1	5.0	532.91						
Upper	P4	524.84	9.7	6.83	531.67	9.7	6.83	531.67	11.6	8.17	533.01						
Till	P5	521.10	15.2	10.70	531.80	15.1	10.63	531.73	16.7	11.76	532.86						
	P6	517.80	19.6	13.80	531.60	19.5	13.73	531.53	21.2	14.92	532.72						
Middle	P7	513.41	25.9	18.23	531.64	26.2	18.44	531.85	27.4	19.29	532.70						
Till	P8	504.83	38.1	26.82	531.65	38.1	26.82	531.65	39.9	28.09	532.92						
	P9	503.76	40.0	28.16	531.92	40.1	28.23	531.99	41.5	29.22	532.98						
	P10	487.97	63.5	44.70	532.67	63.4	44.63	532.60	64.2	45.20	533.17						
(Sand?)	P11	469.74	89.9	63.29	533.03	90.3	63.57	533.31	90.8	63.92	533.66						
Lower	P12	452.00	117.0	82.37	534.37	116.9	82.30	534.30	116.9	82.30	534.30						
Till	P13	441.99	131.2	92.36	534.35	131.5	92.58	534.57	131.8	92.79	534.78						
(Sand?)	P14	428.02	150.74	105.74	533.76	150.4	105.88	533.90	150.6	106.72	534.04						
Alluvial	P15	530.23	1.1	0.77	531.00	1.6	1.13	531.36	3.1	2.18	532.41						
Ox. Till	P16	528.46	3.7	2.60	531.06	3.8	2.68	531.14	5.9	4.15	532.61						
Upper Till	P17	521.82	13.5	9.50	531.32	13.3	9.36	531.18	15.4	10.84	532.66						
	P18	519.59	17.4	12.25	531.84	16.8	11.83	531.42	19.0	13.38	532.97						
Middle	P19	506.89	35.0	24.64	531.53	34.8	24.50	531.39	36.8	25.91	532.80						
Till	P20	486.76	63.9	44.99	531.75	63.4	44.63	531.39	65.0	45.76	532.52						
(Sand?)	P21	469.97	90.0	63.36	533.33	90.2	63.50	533.47	90.7	63.85	533.82						
			*1	*2	*3	*1	*2	*3	*1	*2	*3	*1	*2	*3	*1	*2	*3
Settlement	S1	534.35				123.4	4.13	530.22	155+	?	?						
	S2	534.35				102.5	3.41	530.94	103.4	3.44	530.91						
	S3	534.35				108.6	3.56	530.79	109.1	3.58	530.77						

Settlement Point Calculations

*1 Gauge Reading (psi)

*2 Head Calculation (m) = $\frac{\text{Reading} - \text{Offset}}{\text{Sensitivity}} \times 0.3048$

*3 Elev. Calculation (m) = Reference Elev. - Head

Point No	Offset	Sensitivity	Res. Elev.
S1	2.523	8.921	534.35
S2	3.580	8.848	534.35
S3	4.290	8.924	534.35

Piezometer Calculations

(1) Head H (m) = 0.704 × Reading R (psi)

(2) Elev. (m) = Ref. Elev. E + Head H

Technician:

TABLE 4 - SUMMARY OF SOIL PROPERTIES - Lanigan Division

					ATTERBERG LIMITS							GRAIN SIZE				CONSOLIDATION TEST					TRIAXIAL Ū TEST			
Formation and Material	Hole	Sample Depth (Metres)	% Carbonate	Conductivity (μmhos/cm)	Water Content %	Plastic Limit	Liquid Limit	Plasticity Index	Activity Ratio PI/% clay	Dry Density (kg/m³)	Pocket Penetrometer (kPa)	% Gravel >#4 Sieve	D_{10} 10% Size (mm)	% Fines <.074 mm	% Colloidal <.002 mm	Rowfacs Precons. Pressure P_c (kPa)	Coefficient Consolidation C_v (cm²/sec)	Coefficient Compressibility $a_v \times 10^{-6}$ (cm²/gm)	Compressive Index C_c	Coefficient Volume Compressibility $m_v \times 10^{-6}$ (cm²/gm)	Permeability K (cm/sec)	Moisture %	Dry Unit Wt (gm/cm³)	Cohesion (kPa)
Alluvial Silt	P1	1.6 2.0 1.9-2.1 2.2		104 170	23.7 19.2 24.6	16 17 16	23 22 23	7 5 7	.700 .500 .700	1 507 1 659 1 514	140 120	0	.002	91	10	47	.00387	10.7	.101	0.64	1.7×10^{-8}	22.5	1.868	—
Battleford Till Silty, grey moist, hard low-medium plasticity	P15	1.8 1.9 2.0 2.1-2.6 2.3 2.4-2.5 2.9	11.0	69 460	14.6 14.0 13.5	15 15 17	31 29 31	16 14 14	.800 .700 .700	1 857 1 899 1 916	250 310 350	1	<.001	61	20	100	.00285	12.0	.135	8.1	1.5×10^{-9}	15.2	1.881	88
	P2	3.5 3.5-3.7 3.7 3.9 4.0 4.1 4.2	9.9	162 620 183 300	13.1 15.8 14.3 11.2	17 18 18 18	25 29 27 28	8 11 9 10	.444 .611 .500 .556	1 882 1 880 1 869 1 965	260 330 410 >430	4	<.001	60	18	200	.00019	12.2	.176	8.2	1.5×10^{-9}	15.9	1.880	111
	P16	3.5 3.6-4.0 4.1 4.1-4.3 4.4 4.8		29 150 15 460	13.3 14.0 13.4	18 15 15	31 31 30	13 16 15	.591 .727 .682	1 923 1 873 1 924	340 340 370	1	<.001	61	22	200	.00179	9.3	.139	6.8	1.2×10^{-9}	13.7	1.966	141
	P3	4.3 4.4-4.6 4.5 5.0 5.1		18 760	12.7 14.1 13.1 11.5	16 15 16 17	28 28 29 27	12 13 13 10	.545 .591 .591 .455	1 916 1 849 1 896 1 950	>430 240 >430 >430	2	<.001	65	22	105	.00128	10.8	.138	7.2	9.4×10^{-9}			
	P4	7.3-7.5 7.5 7.5-7.6	8.2	12 970 5 980	9.0 8.9	14 14	22 18	8 4	1.000 .500	2 065 2 165	360	9	.003	36	8	400	.00326	4.2	.069	3.4	10.5×10^{-9}	9.8	2.174	343
Floral Till grey, moist, hard	P17	10.0 10.1-10.6 10.3 11.0-11.1 11.2	10.0	5 240	13.2 12.8 13.6	17 17 16	34 33 31	17 16 15	.773 .727 .682	1 911 1 909 1 906	>430 400 >430	2	<.001	65	22	170	.00051	7.0	.094	4.7	2.4×10^{-9}	13.2	1.888	186
medium plasticity, very stiff	P5	10.5 10.7-10.8 11.1-11.3 11.3-11.4 11.8	15.0	4 830	16.5 16.9 16.8	16 15 18	35 35 38	19 20 20	.760 .800 .800	1 816 1 793 1 797	170 170 190	4	<.001	70	25	130	.00053	10.1	.126	7.3	3.8×10^{-9}	14.9	1.918	98
	P18	12.4 12.6-12.8 13.4 13.0-13.7	14.0	5 660	14.1 13.6 15.1	15 16 16	30 34 33	15 18 17	.833 1.000 .944	1 907 1 890 1 867	>430 370 410	4	<.001	63	18	150	.00057	7.7	.096	5.3	3.2×10^{-9}	12.5	1.964	150
	P6	14.0 14.5-14.6 14.7-14.9 15.2	10.0	5 550	15.6 15.7 14.7	17 17 17	36 33 33	19 16 16	.950 .800 .800	1 858 1 858 1 880	380 240 340	1	<.001	67	20	200	.00133	8.5	.122	6.2	7.8×10^{-9}	15.1	1.897	138
	P7	18.6-19.1 19.1-19.2 19.6	12.0	3 506	14.9 14.5 15.0	17 16 18	32 29 32	15 13 14	.833 .722 .778	1 810 1 886 1 824	330 350 270	3	<.001	62	18	280	.00127	8.3	.124	6.0	7.4×10^{-9}	14.3	1.887	211
	P19	24.7 25.3-25.4 25.5-25.6 25.7	11.0	4 790	11.7 14.0 11.5	17 18 18	36 37 34	19 19 16	.633 .633 .533	1 898 1 826 1 902	>430 360 >430	4	<.001	66	30	270	.00159	7.2	.122	5.3	8.1×10^{-9}	11.0	1.992	346
	P8	25.1 25.9 27.5 27.6-27.7 27.7-27.9 28.0-28.2 28.5		4 120	13.5 14.6 13.9 13.7 13.6	18 18 17 17 17	34 36 36 33 26	16 18 19 16 19	.571 .643 .679 .571 .679	1 824 1 833 1 871 1 891 1 876	>430 340 >430 >430 >430	4	<.001	67	28	350	.00249	10.0	0.100	0.97	1.8×10^{-9}	12.8	1.919	369
	P9	30.6 30.8-30.9 32.0-32.3 32.3-32.5 33.1-33.2 33.4	11.0	3 980	14.2 15.9 16.6	17 18 17	34 33 35	16 15 18	.571 .536 .643	1 790 1 827 1 737	>430 >430 390	2	<.001	68	28	300	.00275	6.9	.122	4.9	14.0×10^{-9}	13.7	1.915	371
Sutherland Group grey, moist, hard, medium plasticity	P10	44.3-44.5 44.8-44.9 45.0-45.3 45.5 46.9-47.1 47.3 48.3	11.0	4 460	15.1 15.9 14.6 15.4 17.1	19 18 19 20 19	42 39 42 43 43	23 21 23 23 24	.719 .656 .719 .719 .750	1 851 1 783 1 826 1 822 1 763	>430 >430 >430 >430 >430	4	<.001	73	32	350	.00127	4.9	.097	3.6	4.7×10^{-9}	15.7	1.878	371
	P20	46.7 47.4 47.5 47.7-48.1	14.0	4 250	16.2 15.9 15.9	17 18 19	42 42 42	25 24 23	.893 .857 .821	1 774 1 766 1 772	— — —	6	<.001	72	28	400	.00124	5.9	.113	4.3	5.4×10^{-9}	16.5	1.898	444
	P21	61.9-62.0 62.0-62.1 62.1-62.4 62.6 62.9 63.3-63.4	5.2 5.2	4 740	16.0 15.4 15.6 14.8	20 19 20 20	48 45 43 43	28 26 23 23	.933 .867 .767 .767	1 798 1 804 1 799 1 898	>430	1	<.001	75	30	300	.00021	6.3	1.03	4.6	0.9×10^{-9}	16.9	1.862	239 325
	P11	62.6-62.7 63.0 63.1-63.3 64.4	5.5	4 950	15.0 15.1	21 21	46 47	25 26	.694 .722	1 844 1 831	>430 >430	2	<.001	76	36	300	.00052	4.6	.075	3.2	6.1×10^{-9}	14.8	1.915	310

	[illegible]	[illegible] 10.0		—	[illegible] 15.0	[illegible] 18	[illegible] 32	[illegible] 14	.722 .778	[illegible] 1 824	330 270	3	<.001	62	18	[illegible]	.00127	8.3	[illegible]	6.0	7.4 x [illegible]	[illegible]	[illegible]	[illegible]
	P19	24.7 25.3–25.4 25.5–25.6 25.7	11.0	4 790	11.7 14.0 11.5	17 18 18	36 37 34	19 19 16	.633 .633 .533	1 898 1 826 1 902	>430 360 >430	4	<.001	66	30	270	.00159	7.2	.122	5.3	8.1×10^{-9}	11.0	1.992	346
	P8	25.1 25.9 27.5 27.6–27.7 27.7–27.9 28.0–28.2 28.3		4 120	13.5 14.6 13.9 13.7 13.6	18 18 17 17 17	34 36 36 33 26	16 18 19 16 19	.571 .643 .679 .571 .679	1 824 1 833 1 871 1 891 1 876	>430 340 >430 >430 >430	4	<.001	67	28	350	.00249	10.0	0.100	0.97	1.8×10^{-9}	12.8	1.919	369
	P9	30.6 30.8–30.9 32.0–32.3 32.3–32.5 33.1–33.2 33.4	11.0	3 980	14.2 13.9 16.6	17 18 17	34 33 35	16 15 18	.571 .536 .643	1 790 1 827 1 737	>430 >430 390	2	<.001	68	28	300	.00275	6.9	.122	4.9	14.0×10^{-9}	13.7	1.915	371
Sutherland Group grey, moist, hard, medium plasticity	P10	44.3–44.5 44.8–44.9 45.0–45.3 45.5 46.9–47.1 47.3 48.3	11.0	4 460	15.1 15.9 14.6 15.4 17.1	19 18 19 20 19	42 39 42 43 43	23 21 23 23 24	.719 .656 .719 .719 .750	1 851 1 783 1 826 1 822 1 763	>430 >430 >430 >430 >430	4	<.001	73	32	390	.00127	4.9	.097	3.6	4.7×10^{-9}	15.7	1.878	371
	P20	46.7 47.4 47.5 47.7–48.1	14.0	4 250	16.2 15.9 15.9	17 18 19	42 42 42	25 24 23	.893 .857 .821	1 774 1 766 1 772	— — —	6	<.001	72	28	400	.00124	5.9	.113	4.3	5.4×10^{-9}	16.5	1.898	444
	P21	61.9–62.0 62.0–62.1 62.1–62.4 62.6 62.9 63.3–63.4	5.2 5.2	4 740	16.0 15.4 15.6 14.8	20 19 20 20	48 45 43 43	28 26 23 23	.933 .867 .767 .767	1 798 1 804 1 799 1 898	>430	1	<.001	75	30	300	.00021	6.3	1.03	4.6	0.9×10^{-9}	16.9	1.862	239 325
	P11	62.6–62.7 63.0 63.1–63.3 64.4 64.5	5.5	4 950	15.0 15.1 17.2	21 21 22	46 47 46	25 26 24	.694 .722 .667	1 844 1 831 1 771	>430 >430 >430	2	<.001	76	36	300	.00052	4.6	.075	3.2	6.1×10^{-9}	14.0	1.915	310
Empress Group grey, damp, hard till low-medium plasticity	P12	79.5 79.6–79.8 79.8–80.0 80.1 80.3–80.5	12.0	3 390	12.4 12.3 13.2	16 16 16	29 28 31	13 12 15	.812 .750 .937	1 921 1 944 1 905	— — —	2	<.001	62	16	300	.00127	6.0	.105	4.3	5.5×10^{-9}	13.8	1.954	295 540
	P13	89.9 90.5 90.8–91.1	9.1		13.3 12.6 12.8	15 17 17	30 31 30	15 13 17	1.00 .867 1.00	1 891 — 1 887	380 >430 >430	2 2	.0012 .0012	62 66	15 17	460	.00619	8.4	.120	6.2	0.4×10^{-9}	13.2	1.980	371
Sand Till	P14	112.8–114.3 161.5										0 4	.05 —	12 31	4 —									

The physical test results are inconclusive as the samples used for the tests may have dried out during the lengthy storage period prior to the samples being tested. Sample drying would result in increased strength values, possible lower water contents and changes in void ratio as discussed in the Section on Laboratory Testing.

Details on the interpretation to estimate the consolidation characteristics of the foundation soils are shown in Tables 1 and 2 inclusive. Table 1 summarizes the results of calculations made to determine the preconsolidation pressure (Pc). Table 2 summarizes the results of calculations made using the consolidation test time curves to determine the coefficient of consolidation (cv), and data from the e-log p plots to determine the coefficient of permeability (k), the coefficients of compressibility (av) and, volume compression (mv) and compressive index (Cc).

Several methods were used to determine the probable preconsolidation loading which the foundation soils have been subjected to. Conventional interpretations of the preconsolidation pressure (Pc) from the e-log p plots of the consolidation tests were made using the Casagrande and Navfacs construction procedures. Other methods utilizing empirical correlations were also used as a check and to obtain a rough estimate of the expected preconsolidation load. The Pc values obtained using the e-log p curve and the conventional Navfac or Casagrande construction procedures interpretation should be in the same general range as those obtained using the empirical correlations based on void ratio and shear strength. With reference to Table 1 a summary and comparison of the average formation preconsolidation load in kPa obtained by the different methods for the different foundation formations is as follows:

	Consolidation e-log p	Empirical void ratio	Empirical (Peck) shear strength
Empress Group	440	577	2 622
Sutherland Till Group	360	550	1 836
Floral Formation	190	532	1 380
Battleford Formation	149	555	1 150
Surficial Silt	43	300	-

The preconsolidation loads determined by the e-log p interpretation are believed to be too low because the maximum loading used in the consolidation test was not high enough to adequately define the coefficient of consolidation (Cc) or the preconsolidation load. The preconsolidation load values estimated from the shear strength are very high. This could be due to drying out of the soil sample prior to testing which would result in higher strength values and estimated preconsolidation loads. Drying out of the soil samples would also affect the void ratio correlation preconsolidation values, but to a lesser extent. For these reasons, and because of the wide range and big difference in the preconsolidation loads determined by the different methods, the test results are not believed to be reliable or representative of the insitu foundation soils. Normally it would be expected that the preconsolidation load values for the same formation should be in the same general range as those obtained by other investigators on the same formations at other sites. A review of the literature gives the following results with the range of preconsolidation loads in kPa listed first with the average value and number of tests averaged in brackets underneath.

Source	Battleford	Floral	Sutherland
McDonald & Sauer - 1970	355 (1)	864 (1)	-
Hamilton and Tao - 1972	244 - 439 371 (4)	732 (1)	-
PFRA - 1985	268 - 450 360 (2)	725 - 860 792 (2)	320 - 645 488 (2)
Overall Summary	244 - 450 365 (7)	725 - 864 795 (4)	320 - 645 488 (2)

These other investigators determined the preconsolidation values using the conventional e-log p interpretation from consolidation test results conducted using maximum test loads in the 40 to over 100 tons per square foot range. These high loads were required to properly develop the coeficient of consolidation (Cc) and define the preconsolidation load (Pc).

There are two possible explanations which could account for the difference between the preconsolidation loads obtained from the test results and those expected based on the results of other investigators. These are first that the foundation soils have not been preconsolidated to any great extent and may in fact be underconsolidated due to the underlying artesian pressure in the Empress Formation, or secondly that the test results are not representative of the insitu foundation soils due to testing load limitations and/or the condition of the soil samples tested. The second explanation is probably the most reasonable. However, based on existing data it is not possible to predict with certainty just what will happen when the foundation is loaded with tails. If the foundation soils have only been slightly preloaded or are underconsolidated due to the underlying artesian pressure, when additional load is applied the insitu pore pressures should increase almost immediately with the applied load. If, on the other hand, the foundation soils have been preconsolidated it would be expected that there would only be a small increase in pore pressures during the initial recompression phase until the preconsolidation load is exceeded, followed by a rapid increase in pore pressures. The accompanying pore pressure increase in the foundation soils due to consolidation in conjunction with the existing artesian regime should be high enough to prevent any downward flow of brine into the Saskatoon Group tills. Dependent on the pore pressures developed in the Saskatoon and Sutherland Group tills relative to those in the underlying Empress Group combined with the upward artesion pressure, vertical pore pressure dissipation from the Saskatoon and Sutherland Group tills could occur in both vertical directions.

Hydrology

Table 2 summarizes the permeability values obtained computed from the results of the consolidation tests. The permeability values obtained fall within the generally accepted range for clay tills. The calculated permeability values would be representative of the permeability of intact till and could be increased by 2 or 3 orders of magnitude in badly fractured tills or a stratified formation like the Empress Group.

The calculated permeabilities are:

Silt	1.7×10^{-8} cm/sec
Battleford Formation	2.2×10^{-8} to 1.5×10^{-9} cm/sec
	average 1.1×10^{-8} cm/sec
Floral Formation	1.8×10^{-9} to 14.0×10^{-9} cm/sec
	average 6.1×10^{-9} cm/sec
Sutherland Group	0.9×10^{-9} to 6.1×10^{-9} cm/sec
	average 4.3×10^{-9} cm/sec
Empress Group Tills	0.4×10^{-9} to 5.5×10^{-9} cm/sec
	average 2.9×10^{-9} cm/sec

Table 3 summarizes the piezometer readings obtained to date and these readings have been plotted on Figures 1 and 2. Some or all of the piezometers may be still in the adjustment phase and therefore may not be registering the correct insitu pore pressure. The piezometers exposed to the Empress Group, P12 to P14 have always indicated a head of +534 metres except for two early readings of P12 which showed the hydraulic head was 0.78 metres above the ground surface at the site. The indicated pore pressures of the other piezometers with the sensors located at higher elevations show a gradual reduction from the high in the Empress Group to near ground level as the ground surface is approached. This pore pressure pattern indicates that the Empress Group is under artesian pressure and that the pore pressure gradually dissipates upwards in the glacial till formations.

Slurry conductivity tests were conducted on a series of representative samples to determine how far brine had migrated downward into the foundation soils. The results of these tests are shown on Figures 1 and 2, and listed in Table 4. The slurry test results indicate that normal background readings were obtained below a depth of 8 metres, with slight salt pollution above this depth from about 4 to 8 metres, and severe contamination in the upper 4 metres with conductivity readings in the range of 100 000 to 200 000 umhos/cm.

As shown by the piezometric reading plots on Figures 1 and 2 ground water flow appears to be in a vertically upward direction at and subsequent to the time of the investigation. The hydraulic head values listed in Table 3 for the Empress Group of 534.04 metres to 534.78 metres are higher than the ground surface Elev. 532.3 metres. The hydraulic heads measured in the various till groups ranged from 532.52 to 533.82 metres in the Sutherland Group, from 532.66 to 533.01 metres in the Floral Formation, and from 532.17 to 532.61 in the Battleford Formation. The pore pressure measured in the shallow surface alluvial silt was 532.13 metres. Horizontal flow may be taking place in the more permeable surficial silt and upper portion of the Battleford Formation. Consolidation of these upper strata with accompanying pore pressure increases would further retard any downward migration and would tend to push the horizontal drainage path of any brine coming from the surface closer to the base of the pile.

Difficulties and Problems

The Contractors work progress is summarized in 'Table 1 Schedule of Work Activities' page 2 of the Contractor's report which is included as Appendix B. In Section 2.3.4 page 10 the Contractor mentions that the major difficulties at this site were the inability to drive casing, maintain fluid return, and the presence of cobbles and boulders which interfered with soil sample core recovery. These problems directly influenced the scope and quality of the final installation.

The drill used by the Contractor, rated at 350 metres of 60 mm drill rod, with a 10 cm x 15 cm piston pump was unable to pump sufficient drilling fluid to maintain circulation while drilling through the waste tailings pile at both sites. This resulted in inadequately cleaned holes and several instances of blind drilling with no cuttings return. The drill was too light with insufficient weight to seat the casing satisfactorily in the underlying clay till in every hole in order to maintain maximum fluid circulation.

The waste tailing pile at PCS Mining, Rocanville Division is situated on an extensive, coarse gravel and cobble foundation with an irregular surface. The original ground surface was leveled prior to the start of pile construction by dozing material from the high spots into the low areas which increased the cobble and boulder depth in the low areas. Under the tailings waste pile the surface gravel thickness encountered was about four metres at the upper Site 2A with a lesser depth of about one metre at the lower Site 1A. Due to lack of fluid return during the drilling it was practically impossible to obtain an accurate log of the upper portion of the foundation or to determine whether the drill was penetrating coarse gravel with cobbles and boulders or glacial till with cobbles and boulders. At the lower Site 1A where the granular surface soils were only about one metre thick the drill crew was able to obtain an adequate seal with the casing in most of the holes. At the upper Site 2A where the depth of granular deposits was about four metres the crew was unable to obtain adequate seals in any of the holes, and long lengths of hole were drilled and cored without fluid return.

The large number of cobbles and boulders encountered in the gravel and the till probably resulted in an irregular and snaky hole profile with major hole deflections from vertical. The hole spacing of five metres between holes probably was sufficient to prevent the intersection of two holes, but at Site 1A a fluid connection was noted between at least three holes during the drilling operation. The irregular hole profile prevented the weighted piezometer tip from falling freely in the hole with the result the tip did not always end up at the desired installation elevation leaving an overlong open hole cavity below the tip.

The soil sample core recovery achieved by the Contractor using an H size core barrel with an impregnated diamond bit and acceptable drilling procedure was drastically reduced by the numerous boulders and cobbles and lack of fluid return. Smaller cobbles tended to jam inside the core barrel preventing entry of additional core or fell into the hole between runs complicating the start of the next run. Slivers of rock cored from the edge of the larger boulders would also jam inside the core barrel preventing the entry of core. At Site 1A excellent core recovery was obtained in the shale including several fractured pieces. However at Site 2A, the shale core recovery was relatively poor as the core tended to slip out of the core catcher despite regular core catcher replacement.

The tailings quickly contaminated the drilling fluid. With the high fluid losses it was impractical to keep the conductivity level of the fluid in the required range to obtain satisfactory electrical logs and it was not considered feasible to construct a pipe line to the drill site to provide an unlimited supply of good water. The conductivity of the drilling fluid when electric logs were run was 6 639 umhos at Site 1A and 2 696 umhos at Site 2A, both much above the desirable level of about 1 500 umhos.

Experience gained from this contract points to the need to use heavier drilling equipment in order to ensure that the objectives of the investigations can realistically be met. Contractors should be prepared to install one to three strings of casing as necessary to ensure the instrumentation sensors can be landed at the desired depth and fluid circulation maintained. Depending on the thickness of the tailings pile, a surface string of casing may be required to the bottom of the pile with a second string to case off the underlying gravel layer. A third string of smaller diameter casing may be required in the till to prevent cobbles from falling back into the hole during or between coring and instrumentation installation procedures. No single conventional type of drill or combination of current drilling procedures are available which would satisfactory deal with all the drilling problems encountered at Rocanville and ensure a satisfactory borehole. From recent experience with this Contract light rotary drills using drilling fluid are not satisfactory and normally lack the means to successfully install casing. A cable tool rig is adapted to setting casing but drilling would be very slow through the salt, cobbles and boulders. The cable tool rig has the additional advantage of being able to go in and out of the hole quickly as circumstances demand which would facilitate the recovery of either disturbed excavator or undisturbed tube type samples and provide better samples and a superior log of the foundation than rotary type drills.

The use of air or foam as the circulating medium with a rotary type drill has been used by some drilling Contractors and has resulted in successful hole completion and better core recovery where other methods failed. However, the technique is not common and requires an experienced crew to achieve optimum results.

Stratigraphy

Figures 3 and 4, summarize pertinent geological and geotechnical data at the two instrumentation sites. The basic logs are based on BBT Geotechnical Consultants Ltd. pilot hole logs for holes 85 - 53, and 85 - 58 for Site 1A, and 85 - 68 for Site 2A, developed from an examination of rotary drill cuttings, the electrical log, drill reaction, and core barrel samples obtained from defined depth intervals. The test results from the laboratory testing and the position of the installed piezometer sensors has been added to the profiles to complete the figures.

The Rocanville tailings waste pile is situated on the edge of a pre-glacial valley which has been infilled with glacial sediments during succeeding glaciations and the sediments eroded one or more times by water from melting glaciers. The QuAppelle River flows along the north side of this pre-glacial valley.

Judging from the limited geotechnical data obtained during the investigation consisting of electric logs of the boreholes and laboratory carbonate content and soil index tests only three till sheets were encountered under the tailings waste pile. The extensive sand layer encountered between elevation 464 and 469 metres is assumed to be an intertill deposit at the top of the Floral Formation and below the Battleford Formation, and could be acting as a drain towards the Qu'Appelle and/or Assiniboine Rivers. The break separating the Sutherland

Group from the lower Floral Formation of the Saskatoon Group is thought to occur within three metres of elevation 458 at both locations.

The identification of the various till sheets has been primarily based on differences in electrical resistance recorded on the electric log and differences in the liquid limits and plasticity characteristics of the tills. Carbonate percentages obtained from tests on samples from different test hole depths fell in the narrow range of 11 to 15.5 percent and as a result are inconclusive as a positive indicator for till sheet identification.

The shale surface was encountered at elevation 445.6 metres at Site 1A and elevation 443.7 metres at Site 2A. The shale has been identified as the Millwood Formation and probably is the weakest foundation strata under the tailings waste pile.

Laboratory Tests and Soil Characteristics

The soil mechanics laboratory tests conducted consisted of index tests such as water content, density, grain size determination and Atterberg limit tests at the location of each piezometer sensor. In addition, physical tests consisting of consolidation tests and B pore pressure response tests were conducted. Slurry conductivity tests and carbonate analyses were carried out on a limited number of samples from selected locations. The results of these tests are summarized in tabular form in Table 8.

Table 5 "Estimation of Preconsolidation Load Pc Rocanville Division" summarizes calculations conducted to estimate the probable preconsolidation loading of the foundation soils utilizing a number of different methods; two methods use the consolidation test e-log p plots and the other methods are based on empirical relationships between undrained shear strength and void ratio to the effective normal pressure

TABLE 5 ESTIMATION OF PRECONSOLIDATION LOAD Pc - ROCANVILLE DIVISION

Assumptions	Site 1A	Site 2A
1. Saturated Tailings Height and Weight	4.3 m @ 400 = 1 720 kg/m^2	6.9 m @ 400 = 2 760 kg/m^2
2. Drained Tailings Height and Weight	7.2 m @ 1 600 = 11 520 kg/m^2	244 m @ 1 600 = 39 040 kg/m^2
3. Total Tailings Height and Weight	11.5 m = 13 240 kg/m^2	31.3 m = 41 800 kg/m^2
4. Saturated soil	1 162 kg/m^3	1 162 kg/m^3

5. Empirical Formula for Pc - $Pc = \frac{1\ 532}{10^{e}}$ for overburden (multiply x 4 for bedrock) in kPa where e is initial void ratio.

6. Peck's Ratio = undrained shear strength to effective normal pressure and the plasticity index $\frac{Su}{P} = .11 + .0037\ Ip$.

7. Navfacs (1961) Ratio Su/P = 0.25 for low plastic clays and 0.35 for highly plastic clays.
8. Conversion Factor 1 kPa ≠ 100 kg/m^2.

* Results believed in error.

Formation	Sample		Present Load kg/m^2	Empirical Check Values Pc (kPa)						Test Results Pc (kPa)				Additional Ht. of Salt to Reach Navfacs Pc	
	Hole	Depth m		e_o	#5 Pc Empirical	Ip	Su kPa	#6 Pc Peck	#7 Pc Navfac	Pc (kPa) Casagrande min	max	Pc (kPa) Navfacs Const.	Pc (kPa) Formation Estimate	Meters	Feet
SITE 1A DATA															
Floral	53	20.3	24 300	.317	738	9	277	1 933	1 108	500	800	800	600	35	115
	53	22.1	26 400	.323	728	12	277	1 794		300	500	450		12	40
Sutherland	53	31.1	36 900	.331	715	17	201	1 162	804	900	1 000	1 000	800	40	130
	58	38.6	45 600	.443	552	19	201	1 115		500	640	600		9	30
Shale	58	41.0	48 400	.795	984	55	205	654	586	600	800	700	900	13	45
	58	42.0	49 500	.715	1 180	71	205	550		650	800	800		19	60
	58	43.8	51 600	.543	1 756	65	205	585		1 100	1 200	1 200		43	140
SITE 2A DATA															
Floral	68	43.0	55 400	.313	745	5	723*	5 626*	2 892*	280	500	500	500	0	0
	68	50.6	64 200	.347	689	11	723*	4 797*		520	700	600		0	0
Sutherland	68	57.9	72 700	.505	479	21	201	1 071	804	500	620	700	600	0	0
Shale	68	68.4	85 000	.529	1 812	53	865*	2 826*	2 471*	760	900	900	900	3	10

Note: Maximum load used in consolidation tests was 3 200 kPa which may not have been high enough to obtain the Pc from the e-log p curve in all cases.

TABLE 6 CONSOLIDATION CHARACTERISTICS AND PERMEABILITY ESTIMATES – ROCANVILLE DIVISION

1. Void Ratio – e_o initial, e_f final.
2. Coefficient of Compressibility $av = e_o - e_1/P_1 - P_o$ cm^2/gm.
3. Coefficient of Consolidation $c_v = 0.197\ H^2/t50$ cm^2/sec or $0.848\ H^2/t90$.
4. Coefficient of Volume Compression $mv = av/1 + e$ cm^2/gm.
5. Compressive Index $Cc = e_o - e_1/\log P_1 \div P_o$. Values for glacial clays usually fall in range of 0.1 to 0.2.
6. Permeability $k = c_v \cdot \gamma\, wa_v / 1 + e$ cm/sec.

Note – Maximum load used in consolidation test was 3 200 kPa.

ITEM			1	1	2	3	4	5	6	6
Formation	Sample Hole	Depth m	e_o	e_f	av $\times 10^{-6}$ cm^2/gm	c_v $\times 10^{-3}$ cm^2/sec	m_v $\times 10^{-6}$ cm^2/gm	Cc	k $\times 10^{-10}$ cm/sec	k $\times 10^{-10}$ average cm/sec
Floral	53	20.3	.317	.243	1.6	1.598	1.2	.083	20.6	63.4
	53	22.1	.323	.235	1.5	8.746	1.2	.083	106.2	
Sutherland	53	31.1	.331	.275	1.8	0.278	1.3	.100	3.9	4.6
	58	38.6	.443	.343	2.2	0.335	1.6	.124	5.4	
Shale	58	41.0	.795	.525	6.8	0.170	4.3	.374	7.3	4.2
	58	42.0	.715	.575	3.6	0.175	2.2	.209	3.9	
	58	43.8	.543	.515	1.2	0.305	0.7	.066	2.4	
Site 2A Floral	68	43.0	.313	.273	0.6	1.358	0.4	.037	7.8	4.6
	68	50.6	.347	.278	1.5	0.592	1.1	.090	1.4	
Sutherland	68	57.9	.505	.380	3.0	0.117	2.7	.166	2.5	2.5
Shale	68	68.4	.529	.491	1.3	0.185	0.8	.070	1.5	1.5

TABLE 7 PCS MINING, ROCANVILLE DIVISION PNEUMATIC INSTRUMENT READINGS

Formation	Tip No.	Ref. Elev. E Metres	Date: May 23, 1985			Date: July 15, 1985			Date: October 2, 1985			Date: October 30-31, 1985			Date:		
			Read R PSI	X.704R Head-H Metres	H + E Elev. Metres	Read R PSI	X.704R Head-H Metres	H + E Elev. Metres	Read R PSI	X.704R Head-H Metres	H + E Elev. Metres	Read R PSI	X.704R Head-H Metres	H + E Elev. Metres	Read R PSI	X.704R Head-H Metres	H + E Elev. Metres
Tailings	P50	476.17	7.5	5.28	481.45	5.6	3.94	480.11	6.5	4.58	480.75	6.75	4.75	480.92			
Upper	P51	470.26	16.5	11.62	481.88	15.1	10.63	480.89	15.25	10.74	481.00	15.5	10.91	481.17			
Till	P52	467.73	19.0	13.38	481.11	18.4	12.95	480.68	18.50	13.02	480.75	18.75	13.20	480.93			
Sand	P55	464.62	23.0	16.19	480.81	20.6	14.50	479.12	156.75?	?		200?					
Lower	P54	462.69	26.0	18.30	480.99	25.3	17.81	480.50	25.25	17.78	480.47	25.6	18.02	480.71			
Till	P53	452.97	40.2	28.30	481.27	39.3	27.67	480.64	153.5?	?		200?					
	P56	446.40	51.0	35.9	482.30	50.0	35.20	481.60	51.25	36.08	482.48	51.75	36.43	482.83			
Shale	P57	444.00	55.0	38.72	482.72	54.2	38.16	482.16	54.75	38.54	482.54	55.5	39.07	483.07			
	P58	440.65	59.4	41.82	482.47	60.4	42.52	483.17	60.75	42.77	483.42	61.5	43.30	483.95			
Tailings	P61	477.53				4.6	3.24	480.77	8.25	5.81	483.34	8.25	5.81	483.34			
Upper Till	P62	471.48				8.8	6.20	477.68	7.60	5.35	476.83	9.5	6.69	478.17			
Sand	P63	466.82				16.1	11.33	478.15	9.50	6.69	473.51	17.0	11.97	478.79			
Lower	P64	458.64				35.5	24.99	483.63	13.80	9.72	468.36	28.0	19.71	478.35			
Till	P65	459.20				26.5	18.66	477.86	13.25	9.33	468.53	35.5	24.99	484.19			
	P66	450.01				41.5	29.22	479.23	50.40	35.48	485.49	54.4	38.30	488.31			
Shale	P67	442.22				87.4	61.53	503.75	92.0	64.77	506.99	93.6	65.89	508.11			
	P68	437.71				93.2	65.61	503.32	98.28	69.19	506.90	100.1	70.47	508.18			
			*1	*2	*3	*1	*2	*3	*1	*2	*3	*1	*2	*3	*1	*2	*3
Settlement	SG1	520.92				69.7	45.12	475.80	69.83	45.21	475.71	69.85	45.22	475.70			

Settlement Point Calculations

*1 Gauge Reading (psi)

*2 Head Calculation (metres) = $\frac{(\text{Reading} - \text{Offset})}{\text{Sensitivity}} \times 0.3048$

$$= \frac{(\text{Reading} - 0.418)}{0.468} \times 0.3048$$

*3 Elev. Calculation (metres) = Reference Elev. - Head

Piezometer Calculations

(1) Head (metres) = .704 Reading (psi)

(2) Elevation (metres) = Reference Elev. + Head

Technician: ____

Date: ____

TABLE 8 - SUMMARY OF SOIL PROPERTIES - ROCANVILLE DIVISION-Site 1A

						ATTERBERG LIMITS						GRAIN SIZE				CONSOLIDATION TEST						TRIAXIAL $\bar{B}$ TEST		
Formation and Material	Hole	Sample Depth (Metres)	% Carbonate	Conductivity (umhos/cm)	Water Content %	Plastic Limit	Liquid Limit	Plasticity Index	Activity Ratio PI/% clay	Dry Density (kg/m^3)	Pocket Penetrometer (kPa)	% Gravel > #4 Sieve	D_{10} 10% Size (mm)	% Fines <.074 mm	% Colloidal <.002 mm	Max. Precons. Pressure P_c (kPa)	Coefficient Consolidation C_v (cm^2/sec)	Coefficient Compressibility a_vx10^{-6} (cm^2/gm)	Compressive Index C_c	Coefficient Volume Compressibility m_vx10^{-6} (cm^2/gm)	Permeability K (cm/sec)	Moisture %	Dry Unit Wt (gm/cm^3)	Cohesion (kPa)
Battleford formation clay till	53	13.7–15.2 15.9–16.7 16.0–16.8	12.0	8 550	10.7 —	15 14	33 24	18 10	.455	1 938		4	<.001	60	22							10.8 Bulge Failure	1.882	277
Fine Sand																								
Floral formation Silty clay till, grey, moist, hard-low plasticity	53	20.3–20.4 20.7–20.9 21.9–22.1 21.2–21.3 22.1–22.2 22.4–22.6 23.0–23.2 23.3–23.5 23.9–24.1	8.9 11.0	16 290 13 370 6 790 10 780	— — 9.1 9.6	14 14 15 15	23 26 26 28	9 12 11 13	.600 .840 .647 .765	2 060 2 016		4 0	<.001 <.001	50 60	15 17	800 450	.00160 .00875	1.6 1.5	.083 .083	1.2 1.2	2.1×10^{-9} 1.1×10^{-8}			
Sutherland Group Silty clay till, grey, moist, hard-medium plasticity	53 58	30.6 30.8–31.1 31.1–31.2 31.7 38.1–38.3 38.5–38.6 38.6–38.7 39.0–39.4 39.7–39.9	12.0 15.0 13.0	10 000 11 990 11 770	16.0 — 9.2 13.5	17 18 17 16	39 35 36 37	22 17 19 21	.815 .630 .731 .808	1 883 — 1 981 1 909		0 2	<.001 <.001	70 64	27 26	1 000 600	.00028 .00035	1.8 2.2	.100 .124	1.3 1.6	3.9×10^{-10} 5.4×10^{-10}	15.1 Bulge Failure	1.769	201
Shale, damp, hard, grey, silty, high plasticity	58	40.7–40.8 41.0 41.1–41.2 41.9–42.0 42.8–43.0 43.6 43.7–43.9 44.5		8 540 12 500	22.5 24.6 19.0 19.7 20.3	24 25 26	79 96 91	55 71 65	1.10 1.37 1.48	1 598 1 651 1 707		0 0 0	<.001 <.001 <.001	96 99 99	50 52 44	700 800 1 200	.00017 .00017 .00030	6.8 3.6 1.2	.374 .209 .066	4.3 2.2 0.7	7.3×10^{-10} 3.9×10^{-10} 2.4×10^{-10}	24.0 Bulge Failure	1.605	204

ROCANVILLE DIVISION-Site 2A

						ATTERBERG LIMITS						GRAIN SIZE				CONSOLIDATION TEST						TRIAXIAL $\bar{B}$ TEST		
Formation and Material	Hole	Sample Depth (Metres)	% Carbonate	Conductivity (umhos/cm)	Water Content %	Plastic Limit	Liquid Limit	Plasticity Index	Activity Ratio PI/% clay	Dry Density (kg/m^3)	Pocket Penetrometer (kPa)	% Gravel > #4 Sieve	D_{10} 10% Size (mm)	% Fines <.074 mm	% Colloidal <.002 mm	Max. Precons. Pressure P_c (kPa)	Coefficient Consolidation C_v (cm^2/sec)	Coefficient Compressibility a_vx10^{-6} (cm^2/gm)	Compressive Index C_c	Coefficient Volume Compressibility m_vx10^{-6} (cm^2/gm)	Permeability K (cm/sec)	Moisture %	Dry Unit Wt (gm/cm^3)	Cohesion (kPa)
Battleford formation silty, clay till, grey, moist, hard, low-medium plasticity	68	35.4 35.5 36.6 37.2 37.6–37.7 37.7–37.8 38.0–38.1 38.2	9.6 8.5 12.7	159 900 171 800 107 100 89 600 114 900	10.9 13.4 18.2 13.0 10.6 18.9	17.9 17.0	29.8 19.7	11.9 2.7	.208	— 1 855	> 430 230 > 430 > 430 > 430	4	<.001	64	13							11.1 (High salt content in sample) Bulge Failure	1.988	51
Fine Sand	68	39.8 40.0 40.3 40.5 40.7	21.1	48 060	15.4 9.5 16.3							0 6	.09 .10	8 9	0 0									
Floral formation silty, clay till, grey, moist, hard, low-medium plasticity	68	41.5 42.0 42.3 42.8–43.0 43.3–43.4 43.5–43.6 45.2–45.3 45.6 45.7–45.8 50.3 50.6–50.7	12.1 15.5 10.0 8.9	41 360 38 880 12 020 8 430 5 050 4 320	10.5 9.9 10.5 9.5 9.1 10.6 9.5 11.8	15.4 15.0 15.5	20.5 27.0 26.2	5.1 12.0 10.7	.425 1.00 .823	1 863 1 904 1 841	> 430 > 430 > 430 > 430	6 6 4	.003 <.001 <.001	52 57 58	9 12 13	500 600	.00136 .00059	0.6 1.5	.037 .090	0.4 1.1	7.8×10^{-10} 1.4×10^{-10}	10.1 (High salt content in sample)	2.038	723
Sutherland Group moist, hard, grey, medium plasticity	68	56.5 57.9 58.7 60.4 61.5 63.5			19.3 14.8 14.4 12.6 13.6	17.8 16.0	38.5 37.0	20.7 21.0	.690	1 679 1 759	320 340 410 380	3	<.001	70	30	700	.00012	3.0	.166	2.7	2.5×10^{-10}			
Clay Shale damp, hard, high plasticity	68	64.2–64.3 65.8 66.9–67.3 67.9 68.4 68.6 69.0			28.0 23.4 20.6 17.6 19.7	30.3 28.8 27.9 27.1	108.0 88.2 102.0 80.8	77.1 59.4 74.1 53.5	.02	1 569 1 649	> 430 > 430 > 430 > 430	0	<.001	96	50	900	.00019	1.3	.070	0.8	1.5×10^{-10}	19.7 (Slick failure)	1.733	865

or preconsolidation load. For these empirical correlations the strength test results obtained from the triaxial $\overline{B}$ shear tests and initial void ratios from the consolidation tests were used. The average preconsolidation load, Pc, obtained by averaging the values obtained from the consolidation test void ratio vs log pressure plots determined by the conventional Casagrande and Navfacs methods of interpretation are probably more representative than the values obtained using the empirical relationships and are in general agreement with the values obtained by other investigators for the same formation strata. The range of Pc values obtained using the e-log p curves, eliminating extremely high values believed in error are:

Shale	600 - 1 200 kPa average 900 kPa
Sutherland Group	500 - 1 000 kPa average 700 kPa
Floral Formation	280 - 800 kPa average 550 kPa

Using these preconsolidation pressure values all of the foundation soils are overconsolidated. Only minimal settlement or pore pressure development should take place until the preconsolidation pressure is exceeded. At Site 1A, with a current tailings depth of 11.5 metres the Pc values indicate that an additional 9 to 43 (average 24) metres of tailings could be added before the preconsolidation load on the foundation is reached and pore pressures in the foundation soils begin to increase rapidly. At Site 2A, with a current tailings depth of 31.3 metres, the load of the tailings pile appears to have exceeded the preconsolidated load of the foundation. Future tailings loads in this area can be expected to be immediately followed by corresponding pore pressure increases in the foundation.

The accompanying pore pressure increase, in the foundation soils as the tails pile load is applied would be high enough to prevent downward flow of brine into the Floral Formation till while consolidation is occurring and probably will be high enough during the recompression phase to prevent downward flow of brine. Since the relative pore pressures developed in the lower shale and Sutherland till should be about the same magnitude or higher than the pore pressure in the Floral Formation, dissipation will likely only occur in an upward vertical direction. The continuous near horizontal intertill sand layer between the Upper Battleford and Lower Floral Formation tills should act as a drain for the upward ground water flow from the underlying foundation soils.

Unfortunately the Contractor was unable to obtain undisturbed samples suitable for laboratory testing from the Battleford Formation due to the large number of cobbles with the result that no test results are available for this till. It would be expected that with loading the permeability would decrease due to void reduction and fracture closure resulting in a decrease in seepage quantities from the overlying tails pile and adjacent waste containment area. This seepage will likely disperse in a horizontal direction in the underlying intertill sand layer. The rate of drainage or pore pressure dissipation will be dependent on the foundation soils permeability.

An interesting difference which should be investigated further is the comparison of the pore pressure in the shale at the two sites. At Site 2A, with about 31 metres of tailings, the pore pressure readings give a hydraulic head of 508 metres while at Site 1A, with about 12 metres of tailings the corresponding pore pressure reading is between 483 and 484 metres, a difference of 24 or 25 metres, which approximately equals the difference in the weight of the tailings placed at each site. This pressure difference could indicate foundation loading by the tailings pile is close to the preconsolidation load in the shale.

Hydrology

Table 6 summarizes the permeability values obtained from calculations using the consolidation test results to determine the permeability of the foundation soils. The values obtained fall within the generally accepted range for clay tills. The calculated permeability values would be representative of the permeability of intact till and could be increased by 2 to 3 orders of magnitude in badly fractured tills.

The calculated permeabilities are:

Floral Formation	1.1×10^{-8} to 1.5×10^{-10} cm/sec average 3.4×10^{-9} cm/sec
Sutherland Group	2.5×10^{-10} to 5.4×10^{-10} cm/sec average 3.9×10^{-10} cm/sec
Shale	1.5×10^{-10} to 7.3×10^{-10} cm/sec average 3.8×10^{-10} cm/sec

Table 7 summarizes the piezometer readings obtained to date from the installed instrumentation and the readings have been plotted on Figures 3 and 4. Some or all of the piezometers may be still in the adjustment phase and therefore may not be registering the proper soil pore pressure. At Site 1A as shown on Figure 3 the July 15/85 set of piezometer readings indicated that the fine sand layer at the P55 installation was probably acting as a drain as the lowest pore pressure reading was in this strata. Later readings, despite the lack of a reading in the sand layer, do not negate this observation. At Site 2A as shown by the pore pressure plot on Figure 4, horizontal drainage appears to be taking place in the surficial gravel layer, Battleford Formation till and intertill sand layer located below the bottom of the waste tailings pile where the lowest pore pressures were monitored in P62 and P63. Below this point the pore pressure tends to increase with depth in the foundation. The pore pressure in the waste tailings pile above (P61) is greater than the pore pressure in P62 and P63, about equal to the pore pressure in the underlying Floral Formation till (P65) and lower than the pore pressures in the underlying Sutherland Formation (P66) and the shale (P67 and P68). The P64 piezometer located in the Floral Formation in the same general depth range as P65 appears to be reading too low. This could be due to a malfunction of the P64 piezometer or the piezometer may not have attained equilibrium conditions as yet.

Slurry conductivity tests to determine the depth of brine contamination into the foundation were run on a series of representative samples. The results of these tests are shown on Figures 3 and 4, and listed in Table 8. The results indicate that normal background readings were obtained at Site 1A with conductivity readings ranging from 6 790 to 12 590 umhos. These values appear much too low and further tests to check these values should be done before the values are accepted. At Site 2A heavy salt pollution occurs for about 3 metres below the base of the pile with readings of 89 600 to 159 900 umhos. Slight pollution occurs in the next 4 to 5 metres with conductivity readings of 38 880 and 48 060 umhos. Normal background conductivity readings of 12 000 or less occur 7 to 8 metres below the bottom of the waste tailings pile.

The decreasing upward piezometric gradient at both sites indicates one way vertical drainage toward the surface is likely taking place from the Sutherland Formation and the shale and that the rate of drainage is very slow indicating relatively impermeable foundation soils. This could have important ramifications in assessing the overall stability of the tailings pile.

CONCLUSIONS

The contractor substantially fulfilled the objectives of the contract and installed the requested geotechnical instrumentation to enable PCS Mining to monitor settlement and formation pore pressure changes in the foundations of two waste tailings piles as the piles increase in height during the next several years. The soil samples obtained during the contract have furnished additional geotechnical information on the soil strata underlying the waste tailings piles at the two sites and provided additional geotechnical data on the engineering properties of the soils to enable engineers to make predictions of the probable behavior of the various soil strata under loading.

Tendering procedures and contract specifications could be improved to ensure an improved standard of contractor performance resulting in better instrumentation installations and more reliable test results. Contract specifications should cover such items as minimum size of drilling equipment to be provided, minimum amount of casing to be used, and the handling and protection of soil samples. More specific instructions covering the physical testing of samples should be included in the contract specifications such as load ranges to be used, reference to CSA and ASTM testing procedures and the use of intact test specimens without hair line fissures. Effective penalties for non-compliance of contract provisions would also provide greater contract control and encourage contract completion on time.

Reliable predictions of future pore pressure response in the foundation due to loading cannot be made based on the laboratory test data obtained, thus the pore pressure readings obtained from the insitu instrumentation will be required in order to predict future pore pressure response in the foundation. Future data obtained by regularly monitoring the installed instrumentation will provide information to enable engineers and researchers to perform future advanced phases of the overall study.

The current investigation indicates that according to pore pressure readings the present fluid flow in the foundations at both sites is upwards. A hydraulic barrier to downward vertical seepage should continue at the Rocanville site since the brine level in the tails pile is probably stabilized. At Rocanville, a comparison of the shale pore pressure readings from the two instrumentation sites indicates that a substantial pore pressure build-up can be expected in the shale as a result of the load applied by the waste tailings pile. Monitoring on a continuing and regular basis should be carried out to determine the rate of pore pressure build-up and dissipation. At Lanigan, barring adverse pressure changes in the underlying artesian aquifer and depending on the stabilized brine level in the proposed tailings pile extension, the current pressure in the underlying aquifer may be insufficient to balance the anticipated head of brine in the tailings pile by 2 or 3 metres of head. However, this will likely not be a problem as flow from both the upper tails pile and underlying foundation tills will likely continue into the intermediate surficial alluvium where it will dissipate horizontally. Frequent monitoring of foundation pore pressures are recommended at Lanigan to confirm that the hydraulic flow in the foundation continues in an upward direction.

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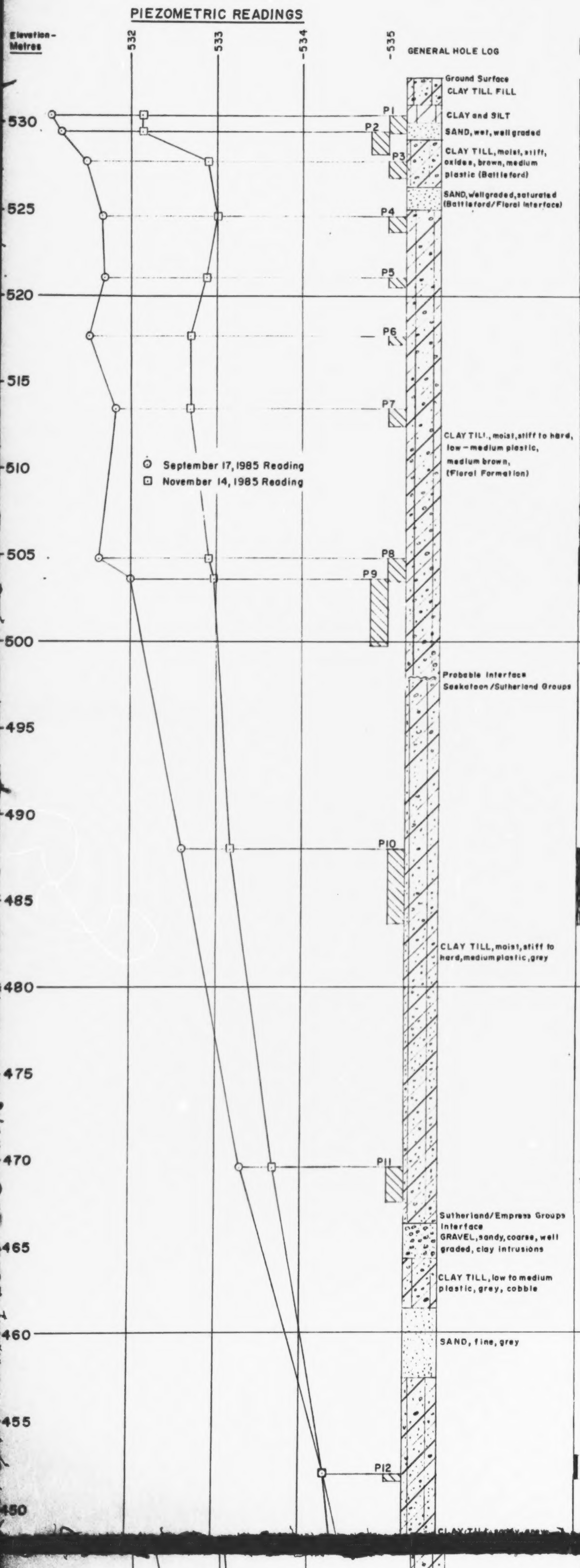
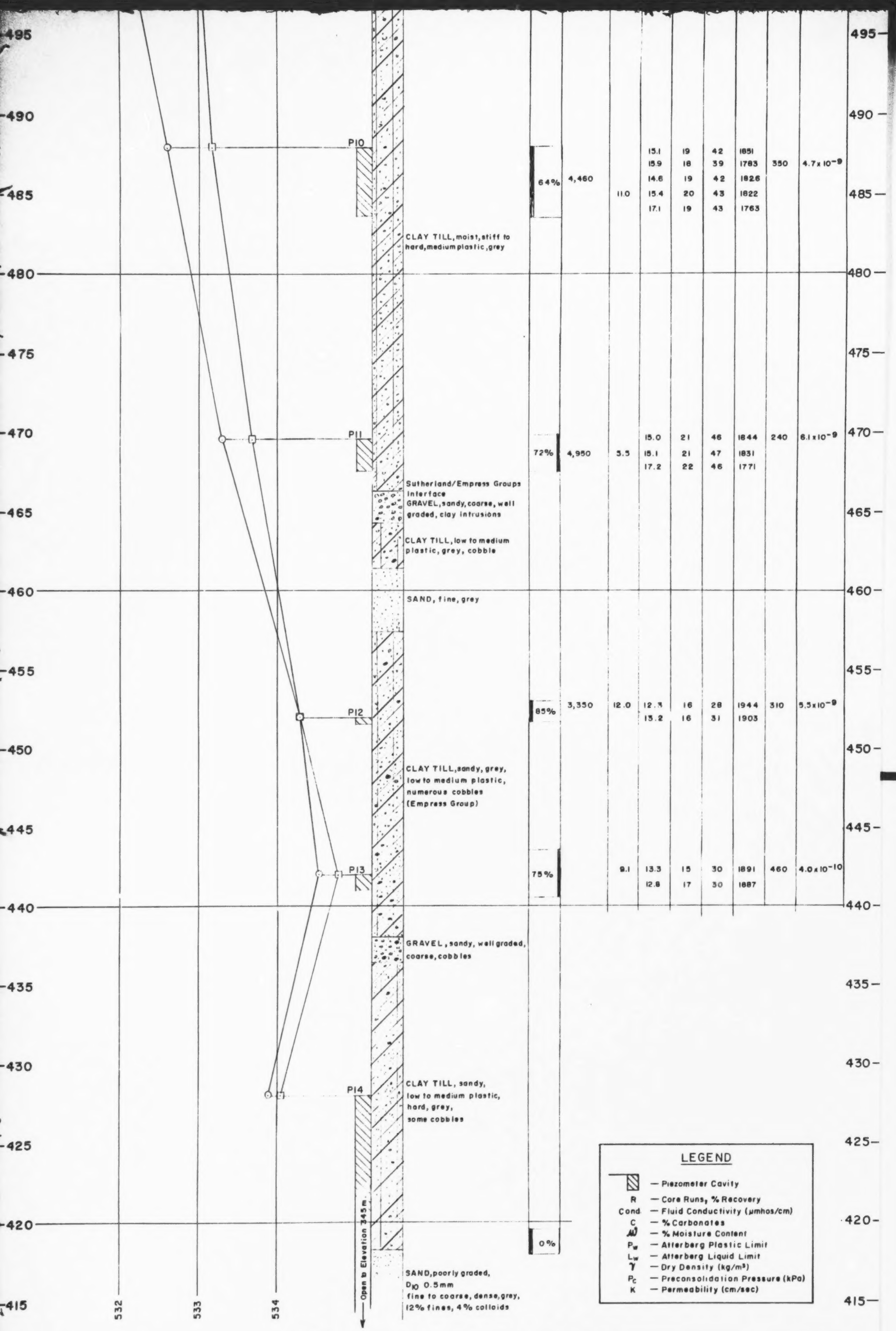
PIEZOMETRIC READINGS

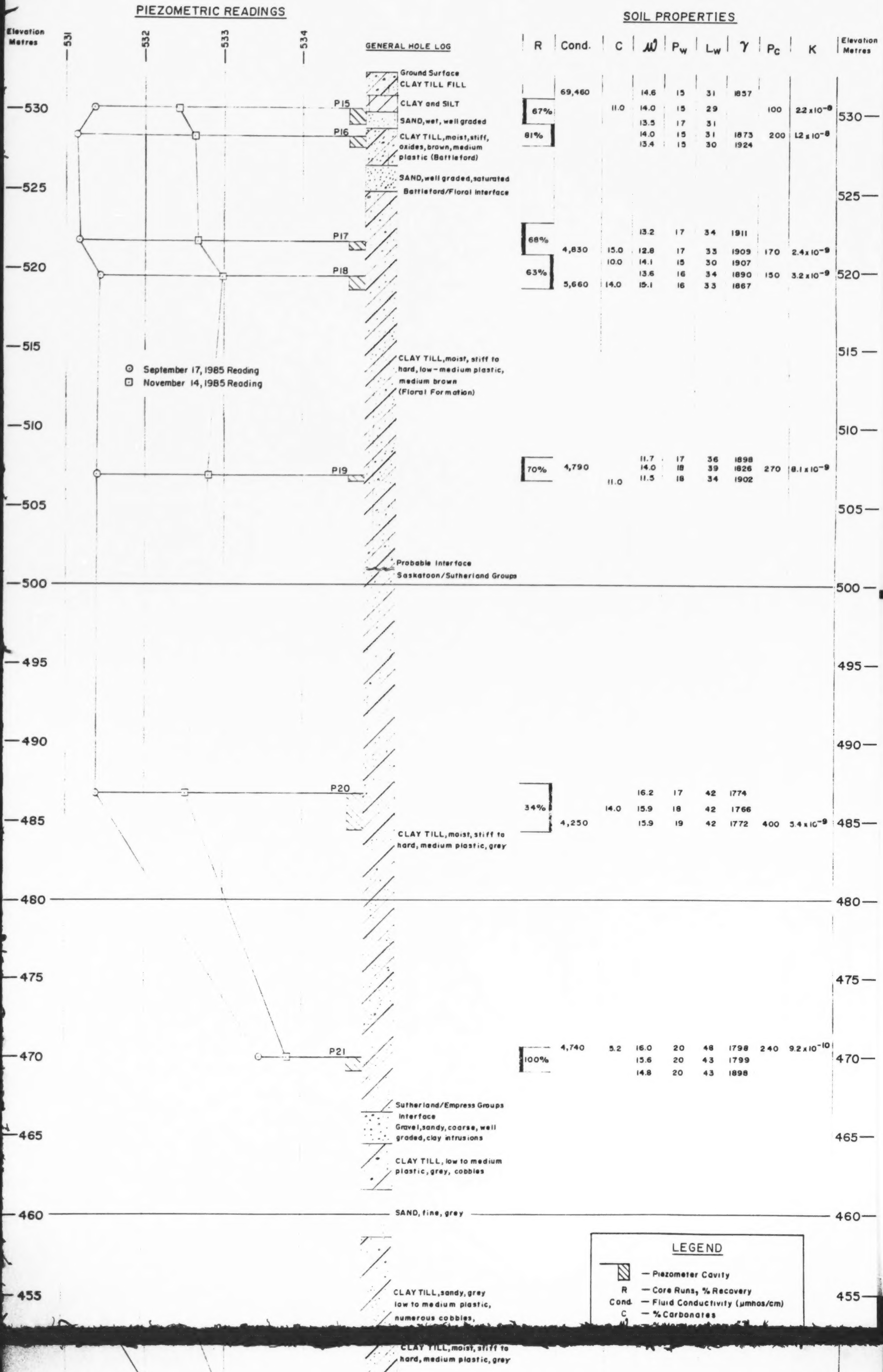


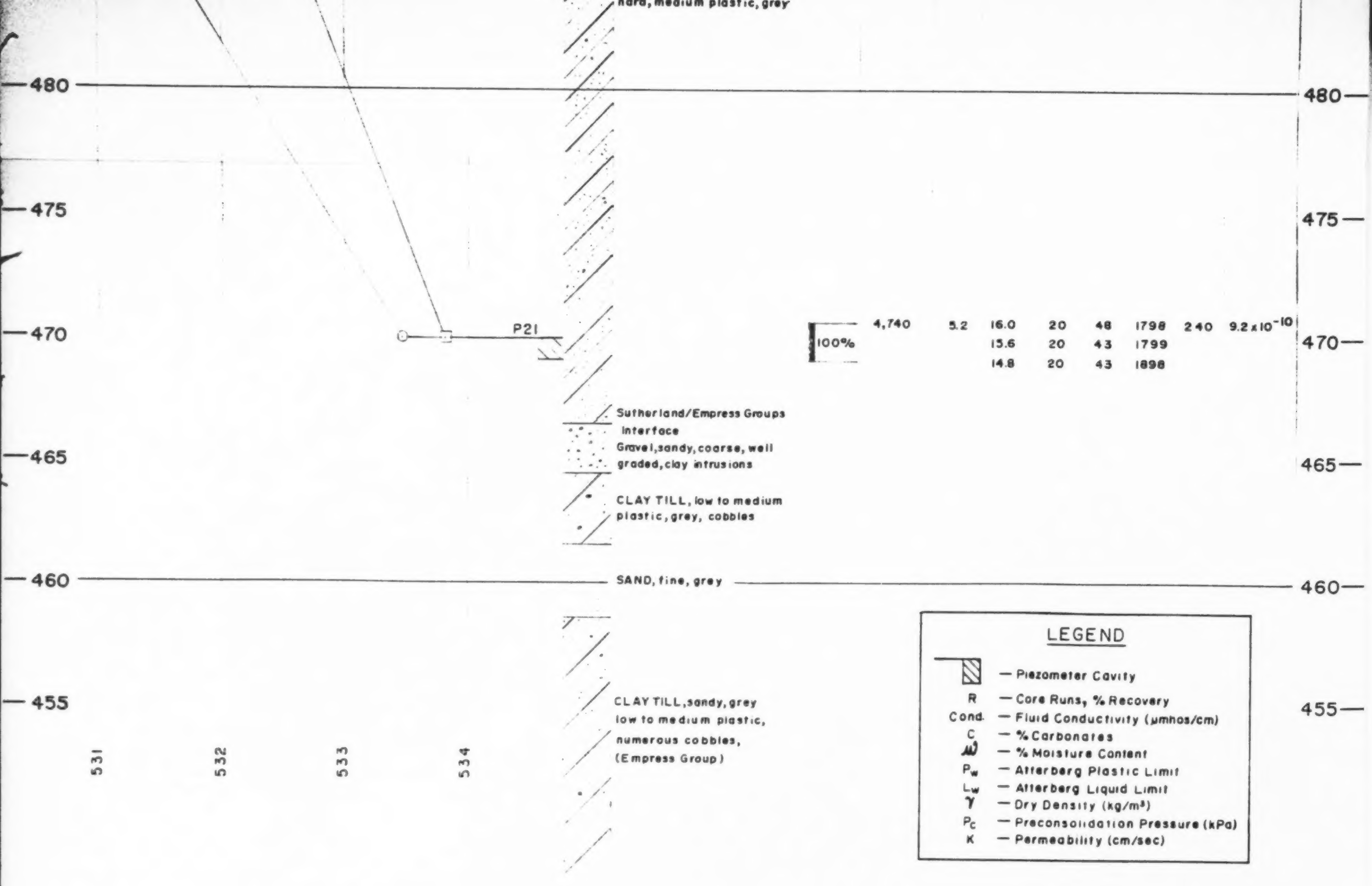
SOIL PROPERTIES

R	Cond.	C	w	P_w	L_w	γ	P_c	K
			23.7	16	23	1507		
	104,170		24.6	16	23	1514	47	1.7×10^{-8}
65%	162,620		13.8	18	29	1880	200	1.5×10^{-9}
	183,300	9.9	14.3	18	27	1869		
100%	18,760		14.1	15	28	1849	90	9.4×10^{-9}
			11.5	17	27	1950		
39%	12,970	8.2	9.0	14	22	2015		
	5,590		8.9	14	18	2165	400	1.0×10^{-8}
			16.5	16	35	1816		
100%			16.9	15	35	1793	130	3.8×10^{-9}
			16.8	18	38	1797		
100%		10.0	13.6	17	36	1858		
	5,550		15.7	17	33	1858	200	7.8×10^{-9}
40%	3,306	12.0	14.9	17	32	1810		
			14.5	16	29	1886	260	$7,4 \times 10^{-9}$
			13.5	18	34	1824		
33%			14.6	18	36	1833		
			13.9	17	36	1871		
	4,120		13.7	17	33	1891	350	1.8×10^{-9}
	3,980		14.2	17	34	1790		
53%			13.9	18	33	1827	300	1.4×10^{-8}
		11.0	16.6	17	35	1737		
			15.1	19	42	1851		
			15.9	18	39	1783	350	4.7×10^{-9}
64%	4,460		14.6	19	42	1826		
		11.0	15.4	20	43	1822		
			17.1	19	43	1763		
			15.0	21	46	1844	240	6.1×10^{-9}
72%	4,950	5.5	15.1	21	47	1831		
			17.2	22	46	1771		
85%	3,350	12.0	12.3	16	28	1944	310	5.5×10^{-9}
			15.2	16	31	1903		


495
490
485
480
475
470
465
460
455
450
445
440
435
430
425
420
415
532
533
534
P10
P11
P12
P13
P14
Open to Elevation 345m
CLAY TILL, moist, stiff to hard, medium plastic, grey
Sutherland/Empress Groups interface
GRAVEL, sandy, coarse, well graded, clay intrusions
CLAY TILL, low to medium plastic, grey, cobble
SAND, fine, grey
CLAY TILL, sandy, grey, low to medium plastic, numerous cobbles (Empress Group)
GRAVEL, sandy, well graded, coarse, cobbles
CLAY TILL, sandy, low to medium plastic, hard, grey, some cobbles
SAND, poorly graded, D10 0.5mm fine to coarse, dense, grey, 12% fines, 4% colloids
64% 4,460 11.0 15.1 19 42 1851 350 4.7x10-9
15.9 18 39 1783
14.6 19 42 1826
15.4 20 43 1822
17.1 19 43 1763
72% 4,950 5.5 15.0 21 46 1844 240 6.1x10-9
15.1 21 47 1831
17.2 22 46 1771
85% 3,350 12.0 12.3 16 28 1944 310 5.5x10-9
13.2 16 31 1903
75% 9.1 13.3 15 30 1891 460 4.0x10-10
12.8 17 30 1887
0%
LEGEND
▧ — Piezometer Cavity
R — Core Runs, % Recovery
Cond. — Fluid Conductivity (μmhos/cm)
C — % Carbonates
ω — % Moisture Content
Pw — Atterberg Plastic Limit
Lw — Atterberg Liquid Limit
γ — Dry Density (kg/m³)
Pc — Preconsolidation Pressure (kPa)
K — Permeability (cm/sec)

SECTION:		LOCATION LANIGAN DIVISION	TITLE
SCALE:	DATE	PCS Mining A Subsidiary of the Potash Corporation of Saskatchewan	FOUNDATION PORE PRESSURES UNDER POTASH WASTE PILES SOIL AND PIEZOMETRIC PROFILE LANIGAN SOUTH SITE
DESIGNED BY:	WCL		PROJECT No
DRAWN BY:	JKOD		BOM No
CHECKED BY:			DRAWING No. FIGURE No. 1
APPROVED BY:			REV △


PIEZOMETRIC READINGS
Elevation Metres
531
532
533
534
530
525
520
515
510
505
500
495
490
485
480
475
470
465
460
455
P15
P16
P17
P18
P19
P20
P21
⊙ September 17, 1985 Reading
⊡ November 14, 1985 Reading
GENERAL HOLE LOG
Ground Surface
CLAY TILL FILL
CLAY and SILT
SAND, wet, well graded
CLAY TILL, moist, stiff, oxides, brown, medium plastic (Battleford)
SAND, well graded, saturated
Battleford/Floral Interface
CLAY TILL, moist, stiff to hard, low-medium plastic, medium brown (Floral Formation)
Probable Interface Saskatoon/Sutherland Groups
CLAY TILL, moist, stiff to hard, medium plastic, grey
Sutherland/Empress Groups Interface
Gravel, sandy, coarse, well graded, clay intrusions
CLAY TILL, low to medium plastic, grey, cobbles
SAND, fine, grey
CLAY TILL, sandy, grey low to medium plastic, numerous cobbles,
CLAY TILL, moist, stiff to hard, medium plastic, grey
SOIL PROPERTIES
R
Cond.
C
w
P_w
L_w
γ
P_c
K
Elevation Metres
69,460 14.6 15 31 1857
67% 11.0 14.0 15 29 100 2.2×10^{-8}
13.5 17 31
81% 14.0 15 31 1873 200 1.2×10^{-8}
13.4 15 30 1924
68% 13.2 17 34 1911
4,830 15.0 12.8 17 33 1909 170 2.4×10^{-9}
10.0 14.1 15 30 1907
63% 13.6 16 34 1890 150 3.2×10^{-9}
5,660 14.0 15.1 16 33 1867
70% 4,790 11.7 17 36 1898 270 8.1×10^{-9}
14.0 18 39 1826
11.0 11.5 18 34 1902
16.2 17 42 1774
34% 14.0 15.9 18 42 1766
4,250 15.9 19 42 1772 400 3.4×10^{-9}
4,740 5.2 16.0 20 48 1798 240 9.2×10^{-10}
100% 15.6 20 43 1799
14.8 20 43 1898
LEGEND
▨ — Piezometer Cavity
R — Core Runs, % Recovery
Cond. — Fluid Conductivity (μmhos/cm)
C — % Carbonates

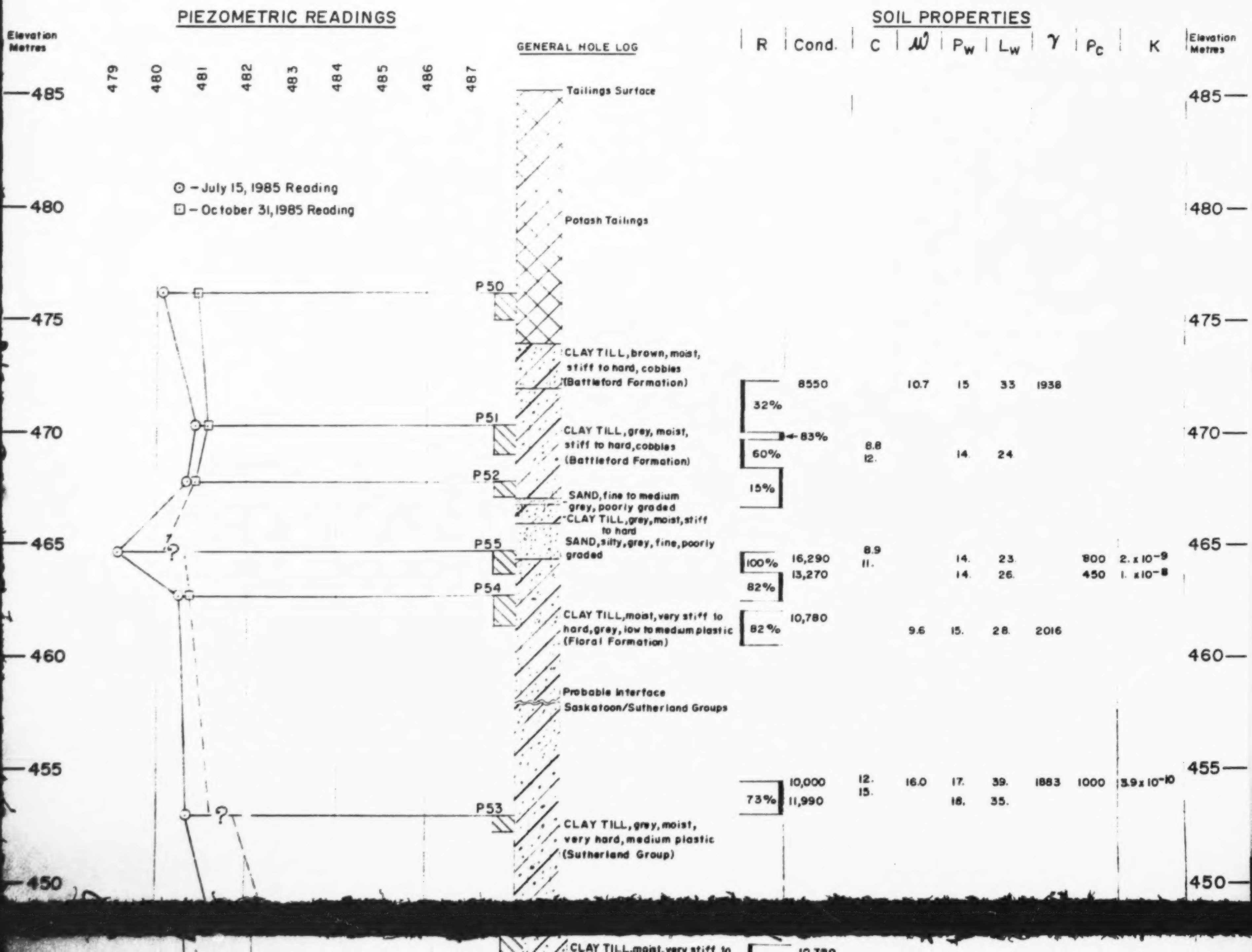

hard, medium plastic, grey
480
475
470
465
460
455
P21
Sutherland/Empress Groups Interface
Gravel, sandy, coarse, well graded, clay intrusions
CLAY TILL, low to medium plastic, grey, cobbles
SAND, fine, grey
CLAY TILL, sandy, grey low to medium plastic, numerous cobbles, (Empress Group)
531
532
533
534
100%
4,740 5.2 16.0 20 48 1798 240 9.2x10^-10
15.6 20 43 1799
14.8 20 43 1898

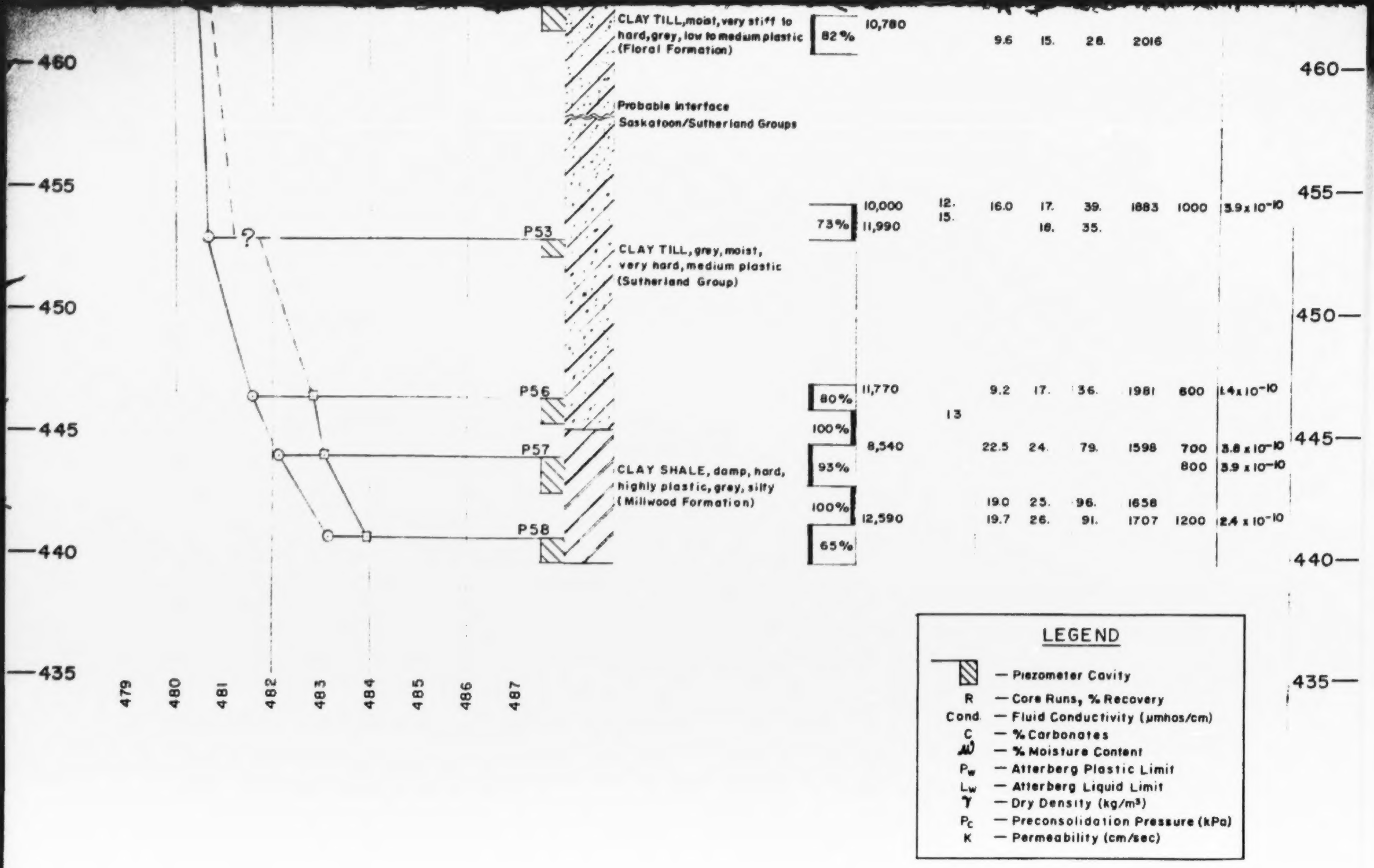
LEGEND

▨	— Piezometer Cavity
R	— Core Runs, % Recovery
Cond.	— Fluid Conductivity (μmhos/cm)
C	— % Carbonates
ω	— % Moisture Content
P_w	— Atterberg Plastic Limit
L_w	— Atterberg Liquid Limit
γ	— Dry Density (kg/m³)
P_c	— Preconsolidation Pressure (kPa)
K	— Permeability (cm/sec)

SECTION:		LOCATION LANIGAN DIVISION	TITLE
SCALE:	DATE	PCS Mining A Subsidiary of the Potash Corporation of Saskatchewan	FOUNDATION PORE PRESSURES UNDER POTASH WASTE PILES SOIL AND PIEZOMETRIC PROFILE LANIGAN NORTH SITE
DESIGNED BY:	WCL		
DRAWN BY:	JKOD		
CHECKED BY:			
APPROVED BY:			

PROJECT No	
BOM No	
DRAWING No. FIGURE No. 2	REV


PIEZOMETRIC READINGS
SOIL PROPERTIES
Elevation Metres
479
480
481
482
483
484
485
486
487
485
480
475
470
465
460
455
450
⊙ – July 15, 1985 Reading
⊡ – October 31, 1985 Reading
P50
P51
P52
P55
P54
P53
?
GENERAL HOLE LOG
Tailings Surface
Potash Tailings
CLAY TILL, brown, moist, stiff to hard, cobbles (Battleford Formation)
CLAY TILL, grey, moist, stiff to hard, cobbles (Battleford Formation)
SAND, fine to medium grey, poorly graded
CLAY TILL, grey, moist, stiff to hard
SAND, silty, grey, fine, poorly graded
CLAY TILL, moist, very stiff to hard, grey, low to medium plastic (Floral Formation)
Probable interface Saskatoon/Sutherland Groups
CLAY TILL, grey, moist, very hard, medium plastic (Sutherland Group)
CLAY TILL, moist, very stiff to
R
Cond.
C
w
P_w
L_w
γ
P_c
K
32%
8550
10.7
15
33
1938
83%
60%
8.8
12.
14.
24
15%
100%
82%
16,290
13,270
8.9
11.
14.
14.
23.
26.
800
450
$2. \times 10^{-9}$
$1. \times 10^{-8}$
82%
10,780
9.6
15.
28.
2016
73%
10,000
11,990
12.
15.
16.0
17.
18.
39.
35.
1883
1000
3.9×10^{-10}
10,780


460
455
450
445
440
435
479
480
481
482
483
484
485
486
487
?
P53
P56
P57
P58
CLAY TILL, moist, very stiff to hard, grey, low to medium plastic (Floral Formation)
Probable interface Saskatoon/Sutherland Groups
CLAY TILL, grey, moist, very hard, medium plastic (Sutherland Group)
CLAY SHALE, damp, hard, highly plastic, grey, silty (Millwood Formation)
82%
73%
80%
100%
93%
100%
65%
10,780 9.6 15. 28. 2016
10,000 12. 15. 16.0 17. 39. 1883 1000 3.9 x 10⁻¹⁰
11,990 18. 35.
11,770 9.2 17. 36. 1981 600 1.4 x 10⁻¹⁰
13
8,540 22.5 24. 79. 1598 700 3.8 x 10⁻¹⁰
800 3.9 x 10⁻¹⁰
19.0 25. 96. 1658
12,590 19.7 26. 91. 1707 1200 2.4 x 10⁻¹⁰
460
455
450
445
440
435
LEGEND
— Piezometer Cavity
R — Core Runs, % Recovery
Cond. — Fluid Conductivity (μmhos/cm)
C — % Carbonates
ω — % Moisture Content
Pw — Atterberg Plastic Limit
Lw — Atterberg Liquid Limit
γ — Dry Density (kg/m³)
Pc — Preconsolidation Pressure (kPa)
K — Permeability (cm/sec)

SECTION:		LOCATION ROCANVILLE DIVISION	TITLE	PROJECT No
SCALE:	DATE	PCS Mining A Subsidiary of the Potash Corporation of Saskatchewan	FOUNDATION PORE PRESSURES UNDER POTASH WASTE PILES SOIL AND PIEZOMETRIC PROFILE ROCANVILLE SITE IA	B O M No.
DESIGNED BY:	WCL			
DRAWN BY:	JKO'D			DRAWING No. FIGURE No. 3
CHECKED BY:				REV
APPROVED BY:				